US 20060032702A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2006/0032702 A1**

Linsmeier et al. (43) **Pub. Date: Feb. 16, 2006**

(54) **COMPOSITE BOOM ASSEMBLY**

(75) Inventors: **Eric Linsmeier**, Larsen, WI (US); **David W. Archer**, Hortonville, WI (US); **Robert M. Hathaway**, Oshkosh, WI (US)

Correspondence Address:
FOLEY & LARDNER LLP
777 EAST WISCONSIN AVENUE
SUITE 3800
MILWAUKEE, WI 53202-5308 (US)

(73) Assignee: **Oshkosh Truck Corporation**

(21) Appl. No.: **10/996,665**

(22) Filed: **Nov. 24, 2004**

Related U.S. Application Data

(63) Continuation-in-part of application No. 10/902,497, filed on Jul. 29, 2004.

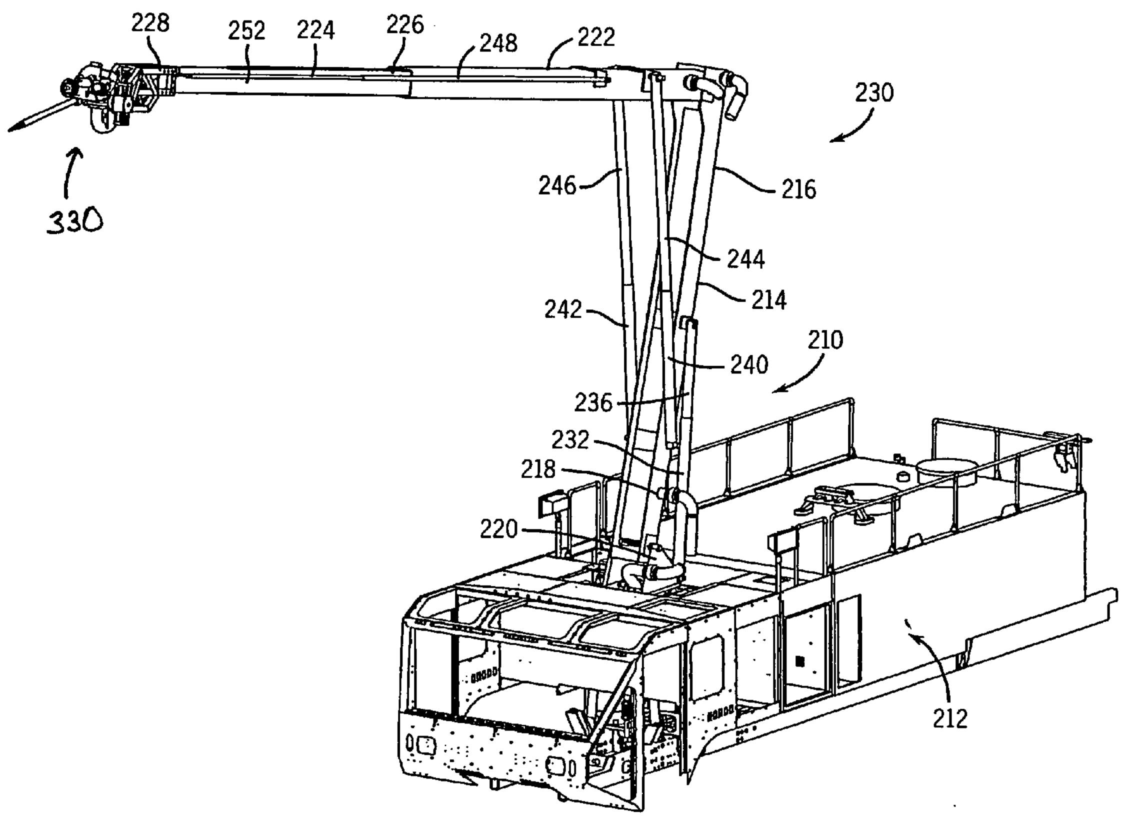
Publication Classification

(51) **Int. Cl.**
E04G 1/00 (2006.01)

(52) **U.S. Cl.** **182/2.3**

(57) **ABSTRACT**

An aerial boom assembly comprising a first member having a fixed length and comprising first and second ends, the second end being pivotally coupled to a mobile base. The aerial boom assembly comprises a second member pivotally coupled to the first member at the first end, the second member comprising an extension member slidably coupled to the second member along an inner channel of the second member. The first and second members are made from a composite material comprising a reinforcement material in a polymeric matrix.



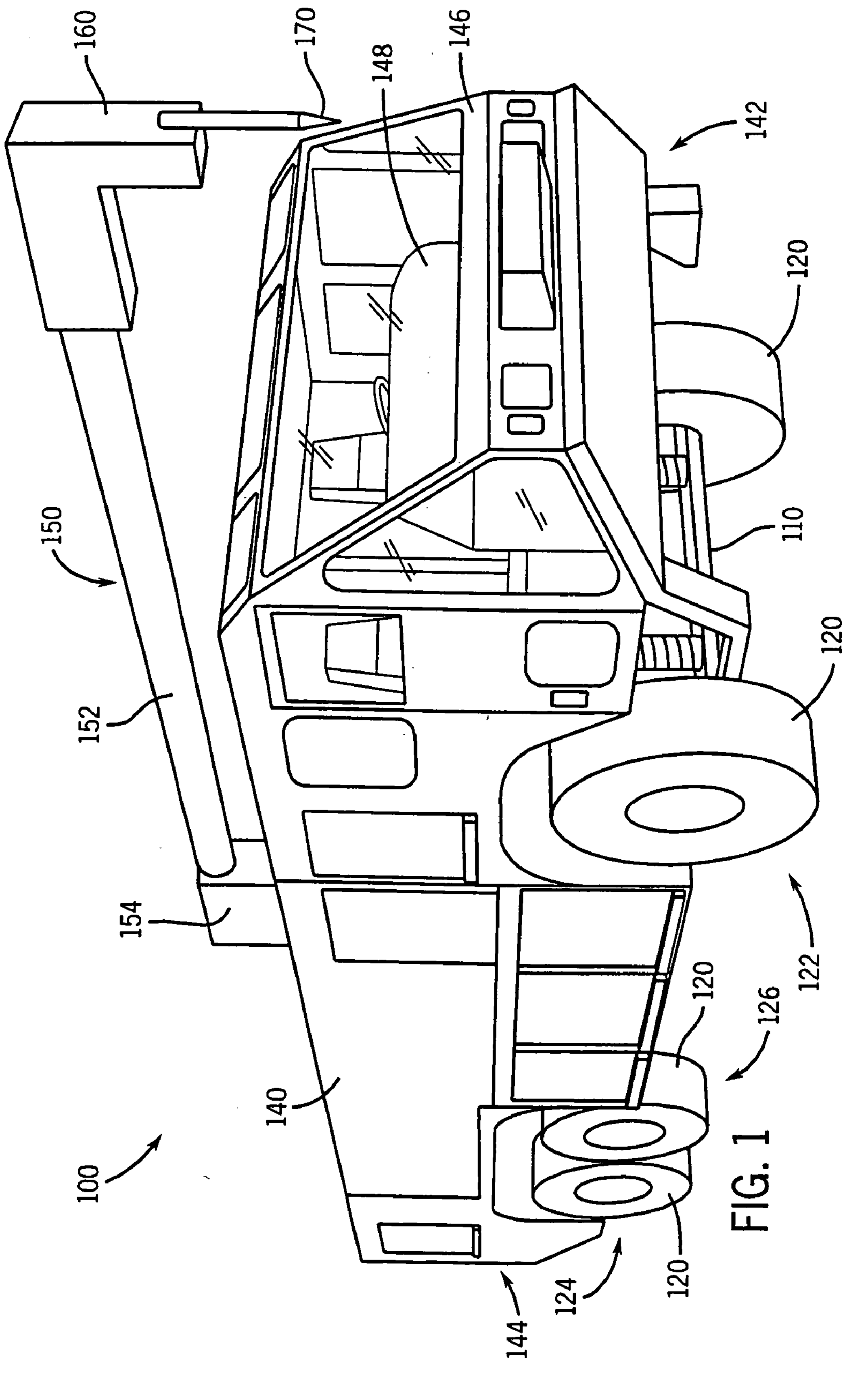

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FIG. 1

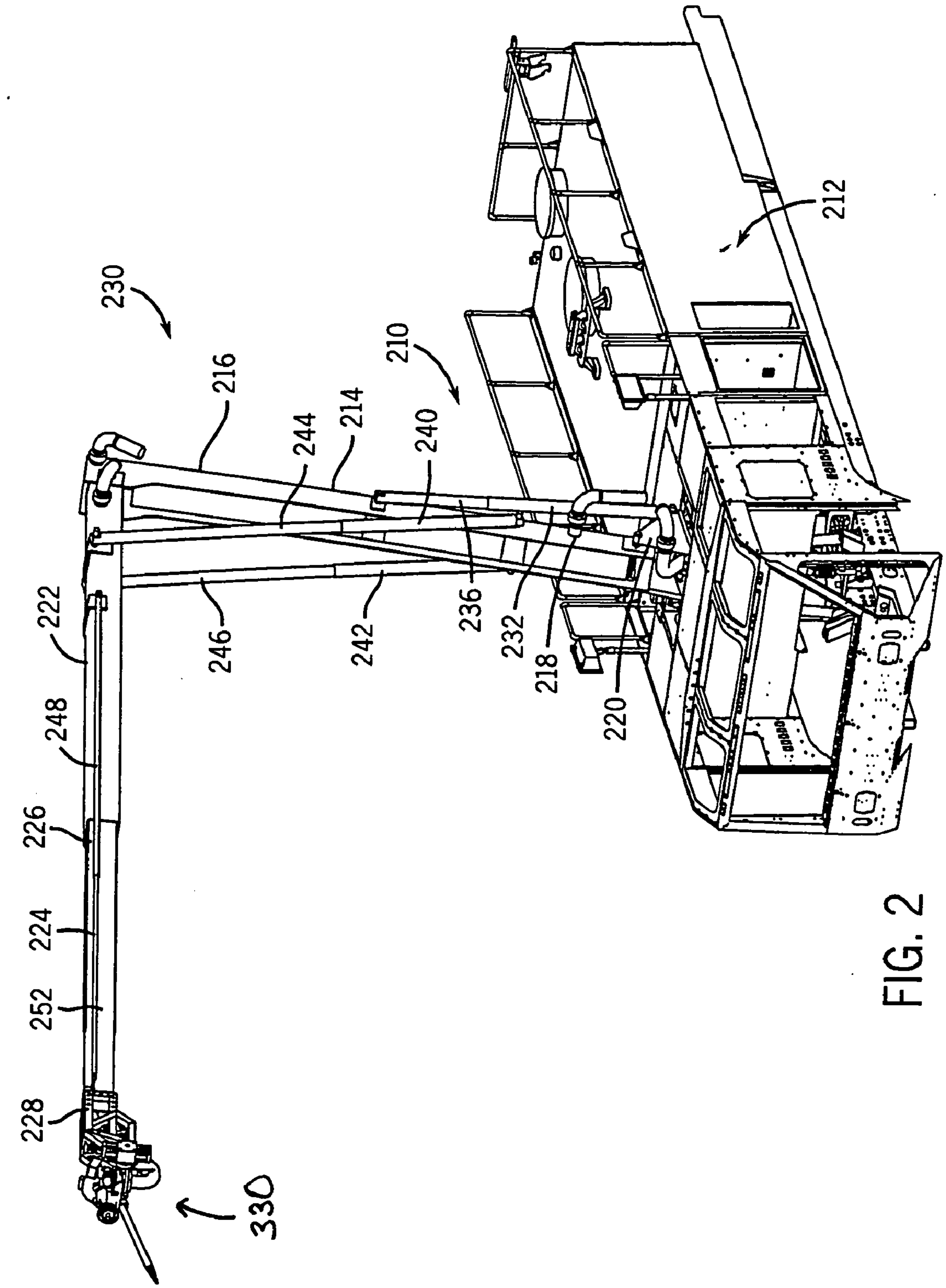
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FIG. 2

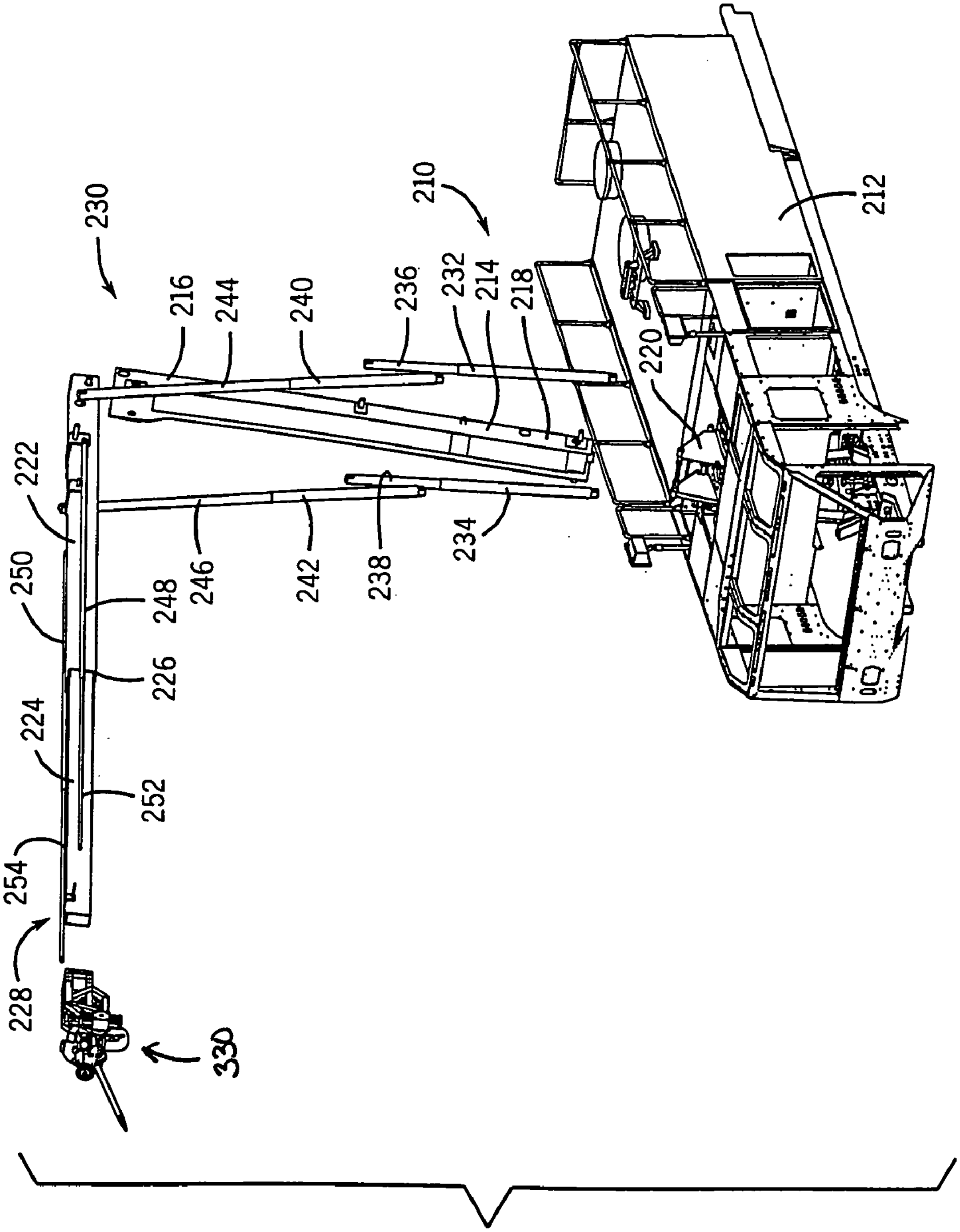
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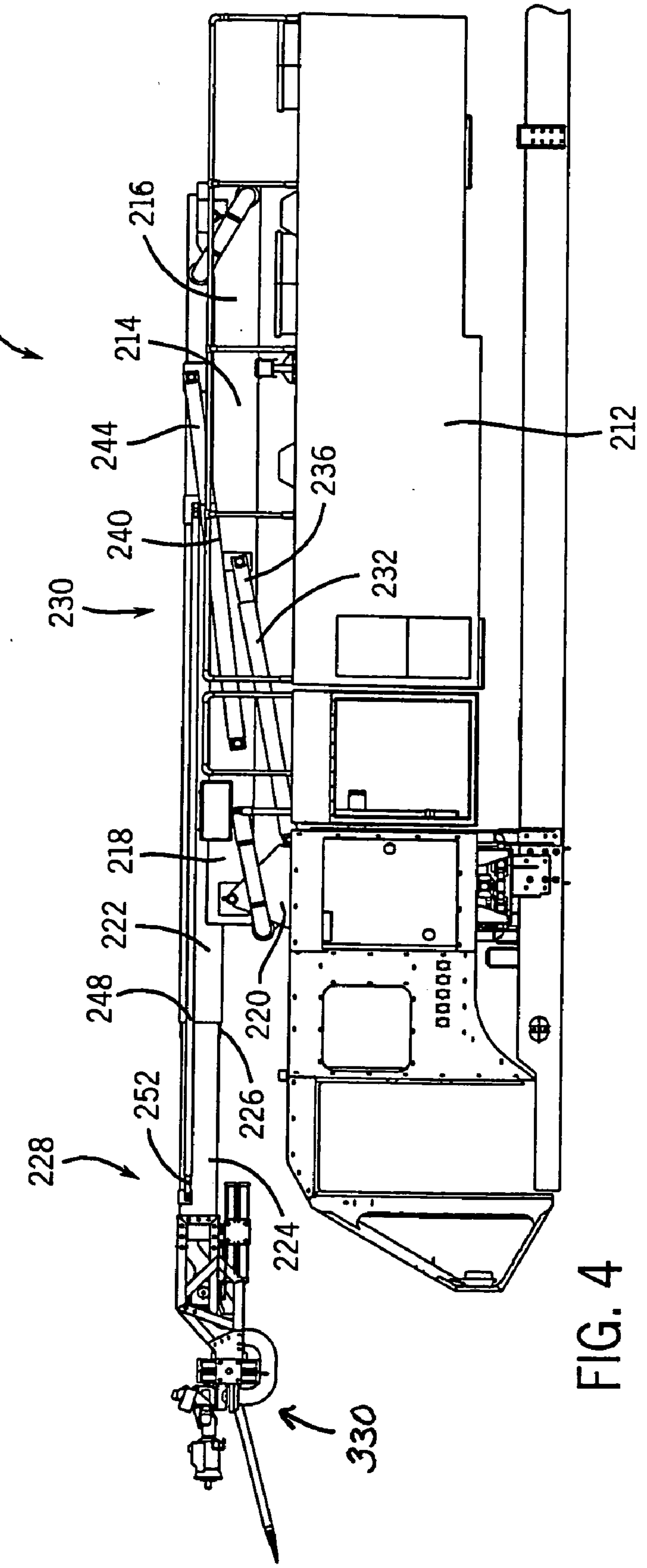
FIG. 3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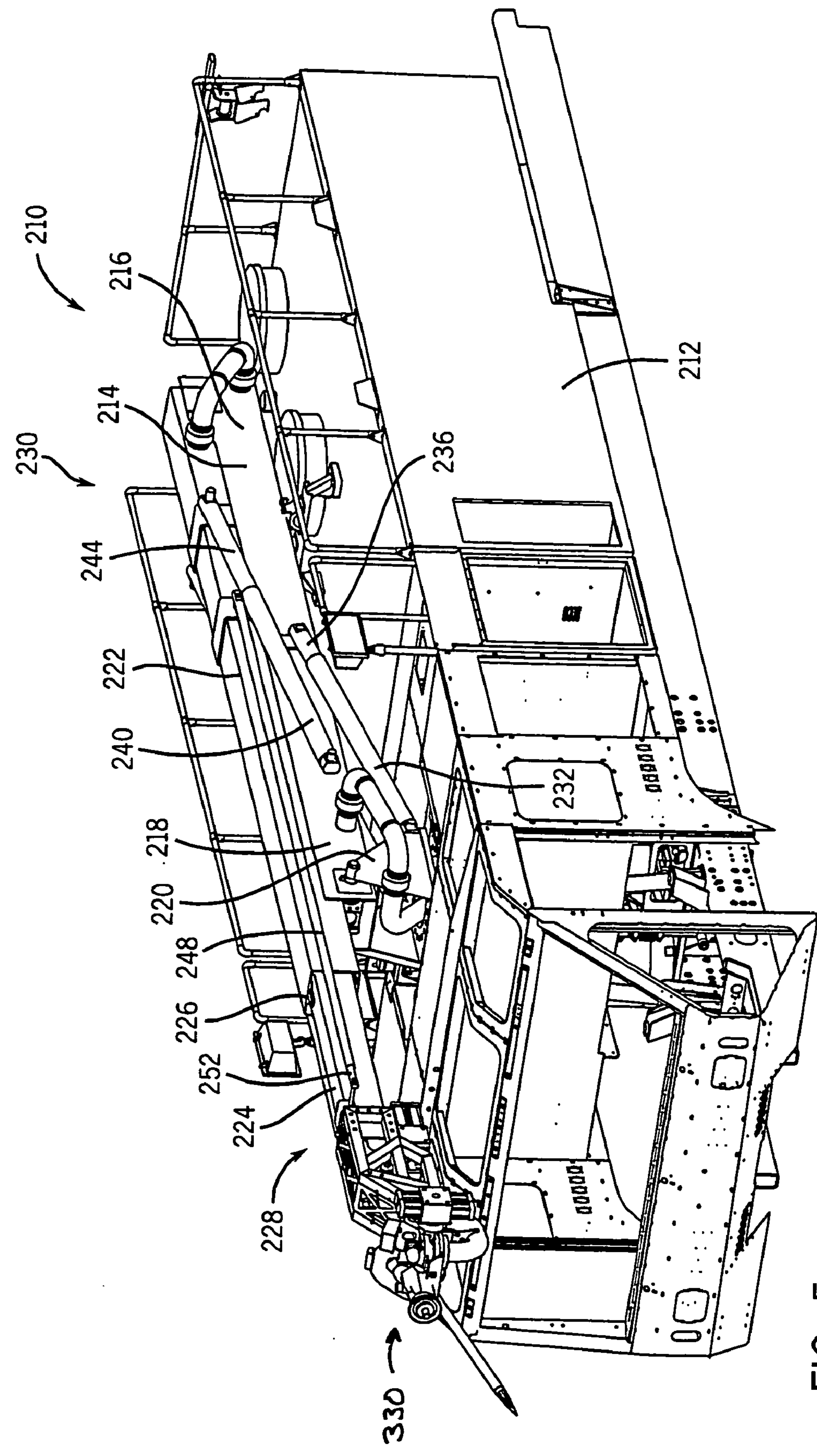
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FIG. 5

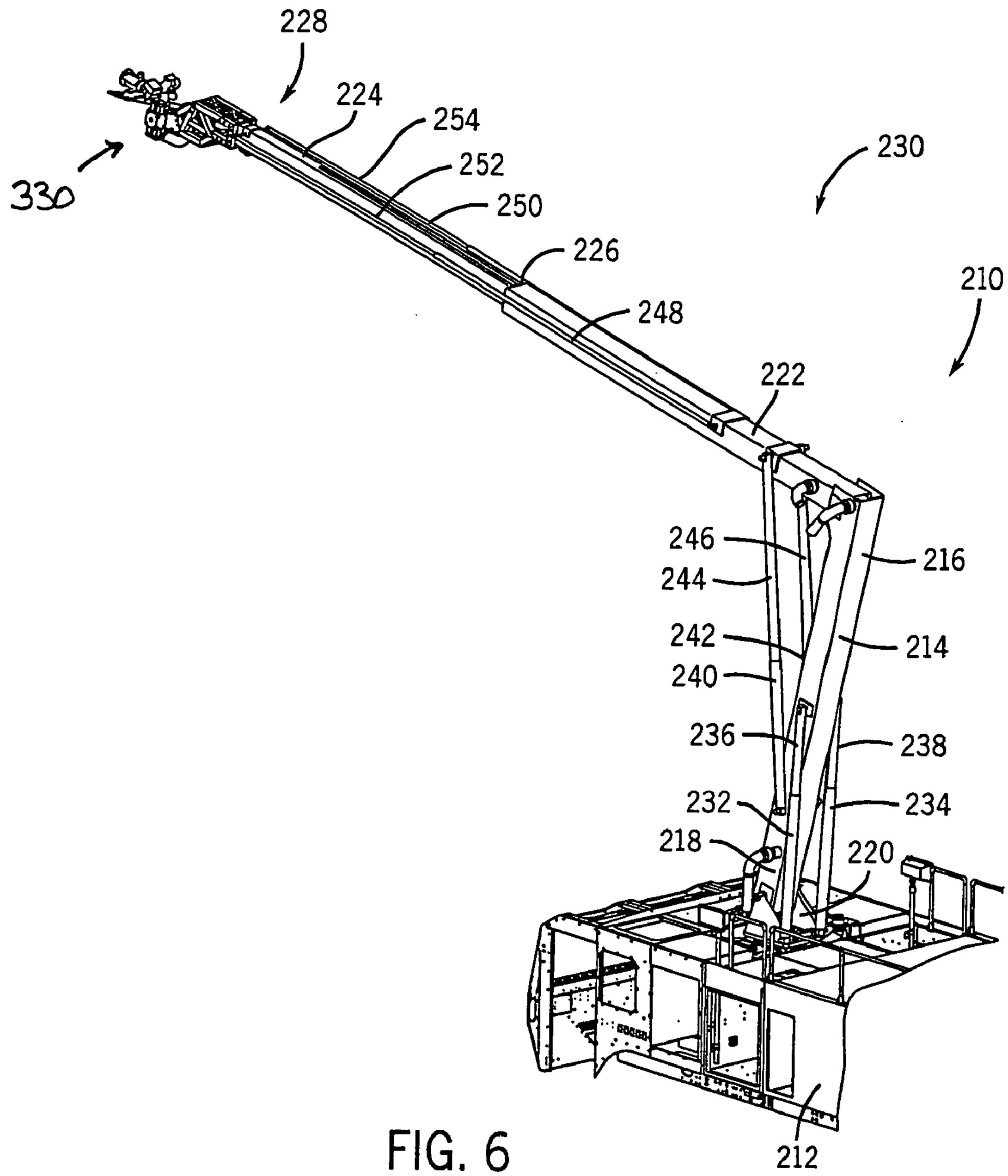
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FIG. 6

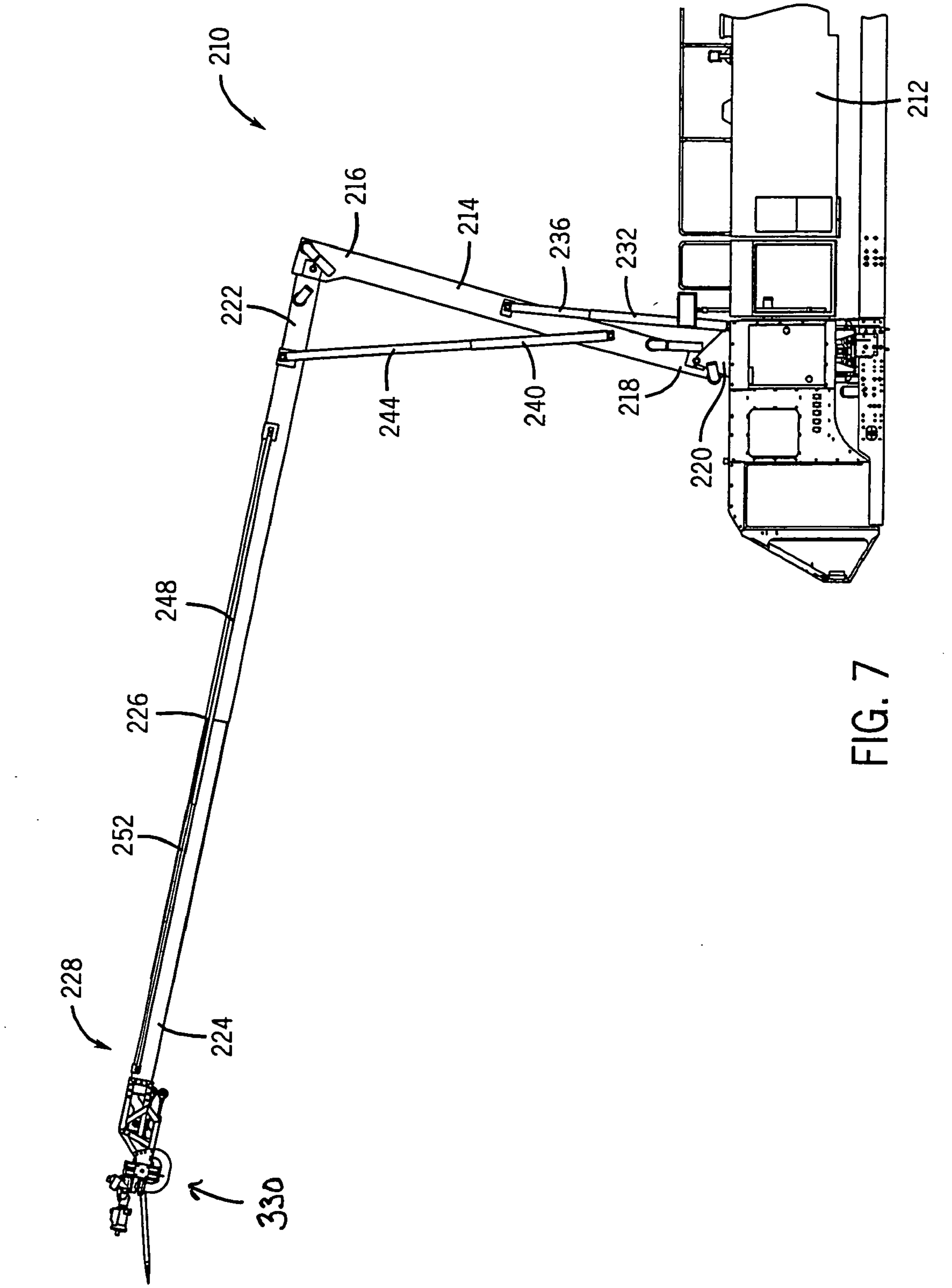
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FIG. 7

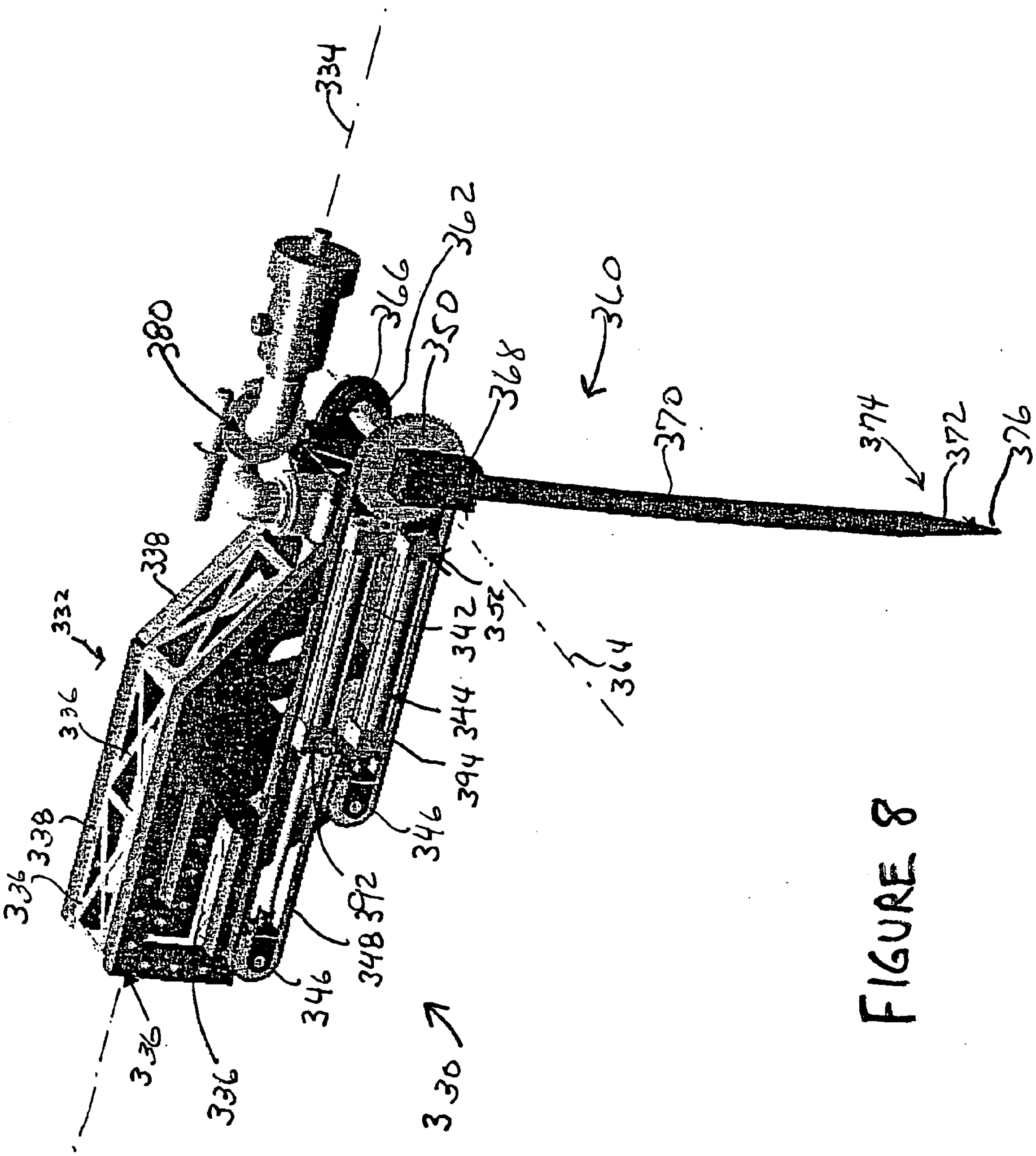

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FIGURE 8

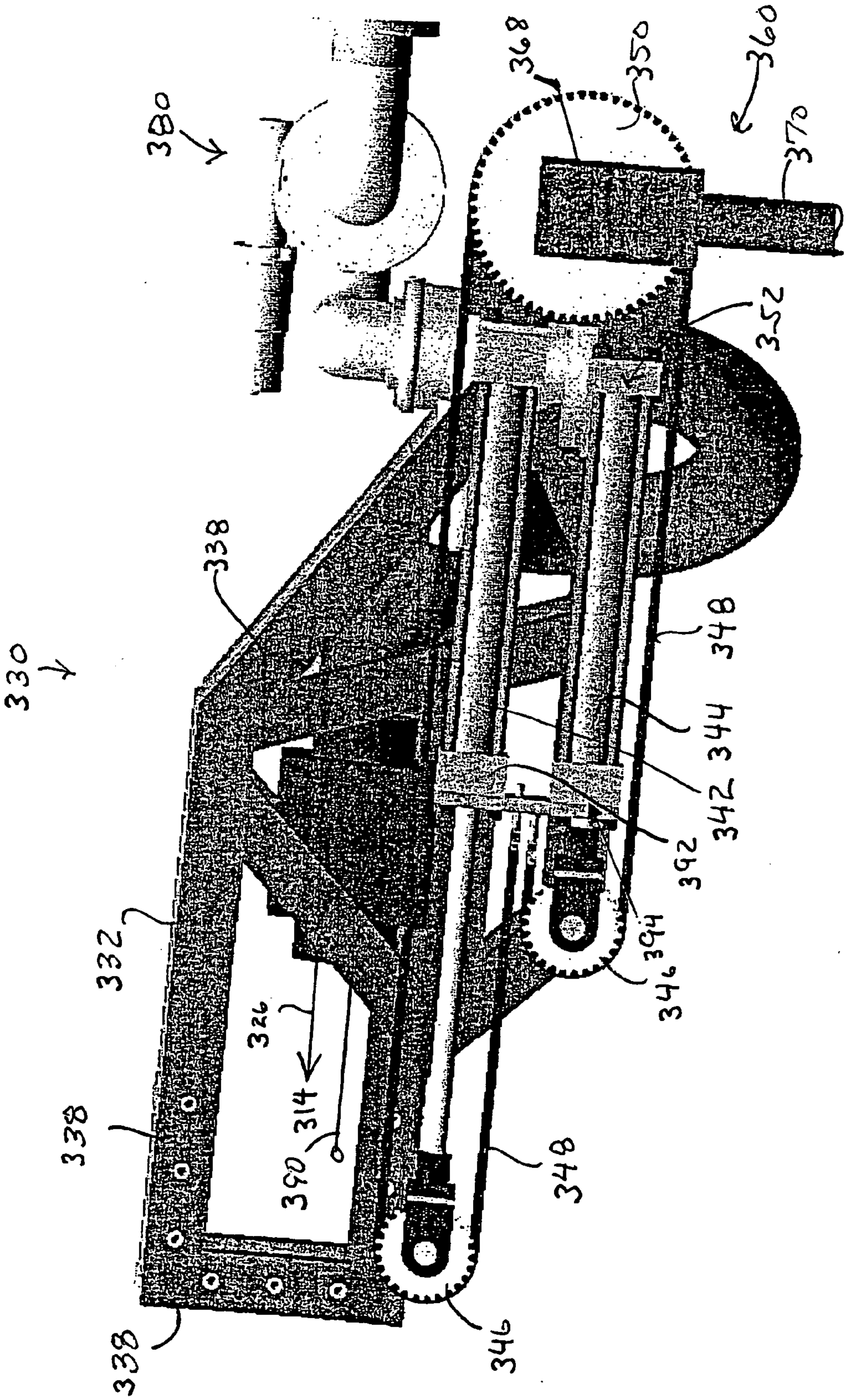
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FIGURE 9

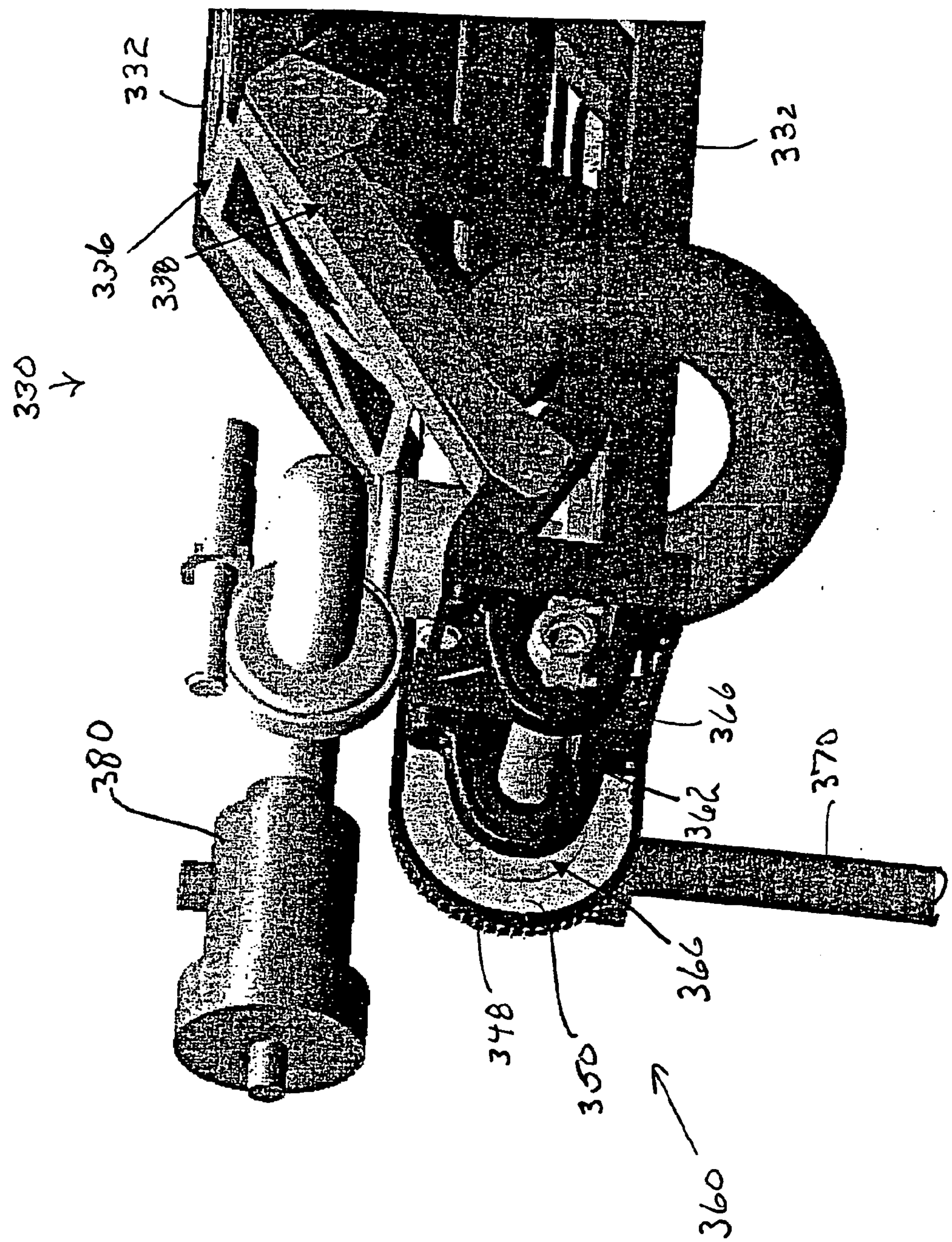

FIGURE 10

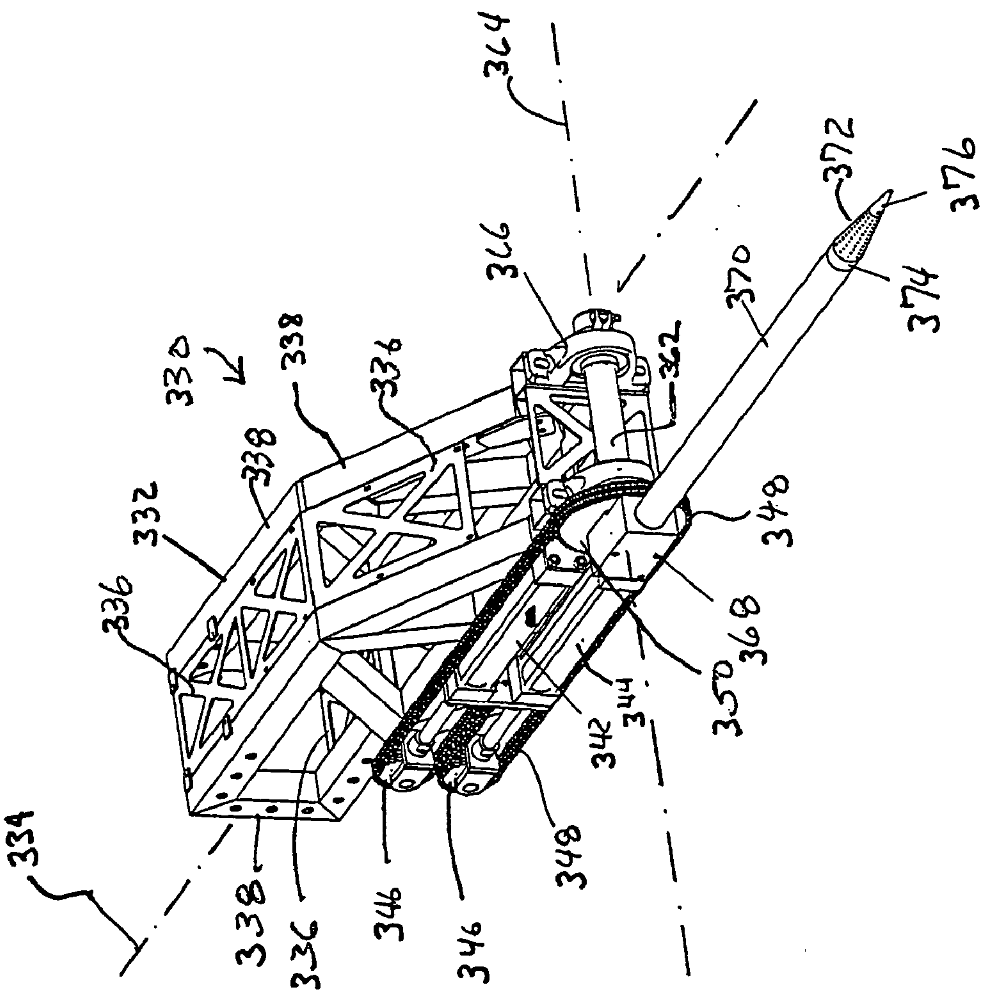
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FIGURE 11

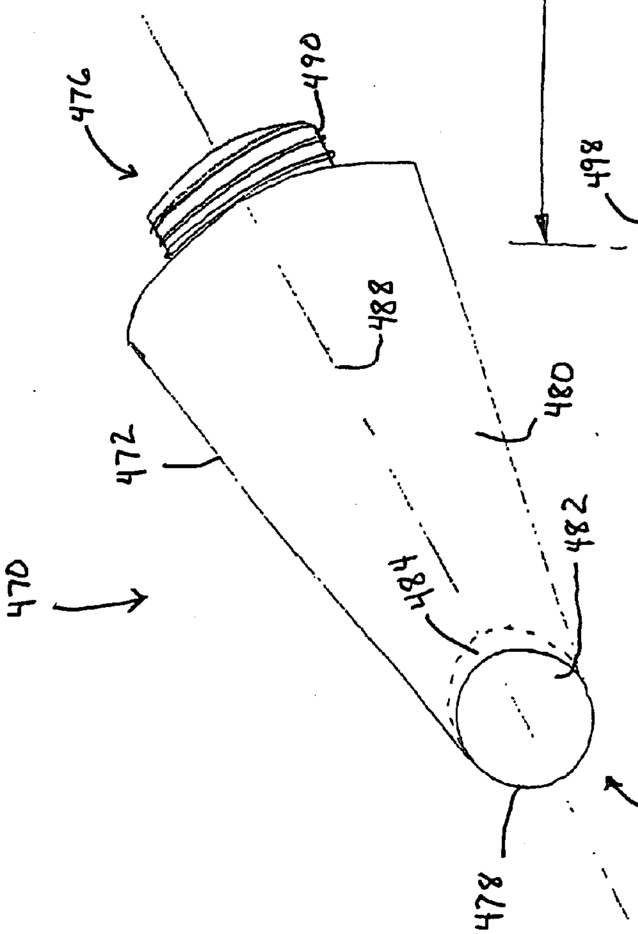

FIGURE 12

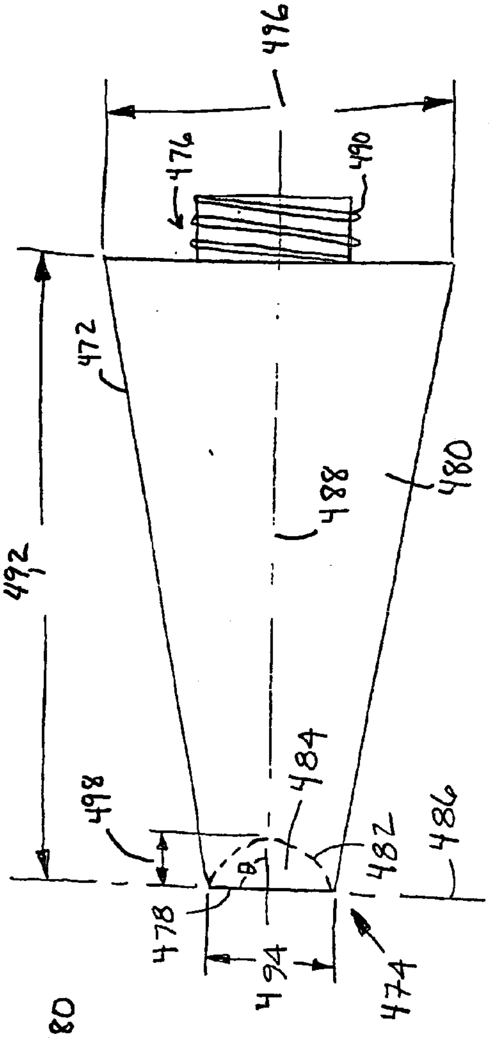

FIGURE 13

COMPOSITE BOOM ASSEMBLY

CROSS-REFERENCE TO RELATED PATENT APPLICATIONS

[0001] This application is a continuation-in-part application of co-pending U.S. application Ser. No. 10/902,497 filed on Jul. 29, 2004, from which priority is claimed under 35 U.S.C. § 120. The full disclosure, in its entirety, of U.S. application Ser. No. 10/902,497 is hereby incorporated by reference.

FIELD

[0002] The present invention relates to devices for firefighting and rescue operations. In particular, the present invention relates to a composite aerial boom assembly for use with firefighting and/or rescue vehicles.

BACKGROUND

[0003] Many different types of vehicles utilize aerial boom systems for firefighting and/or rescue operations. In general, aerial boom systems are configured to extend from a vehicle or other structure and elevate to a predetermined height. Some aerial boom systems are also configured to tilt and adjust along various axes. Typically, aerial booms include hollow piercing nozzles on the outer ends which are configured to pass through a wall or other structure (e.g., aircraft fuselage) to the interior of the structure where fire-retardant material or other liquid may be released. Because of the demanding conditions involved with fires and other rescue operations, steel is a common material for constructing aerial boom systems. Steel is very strong, stiff, and durable and is usually able to maintain its mechanical and physical characteristics (e.g., strength) during firefighting and rescue operations.

[0004] Although steel has high strength & stiffness characteristics, it has a relatively low specific strength (i.e., strength/density ratio). This can prove problematic because of the need to decrease the weight of firefighting vehicles and devices. Less vehicle weight allows for better performance of the vehicles (e.g., cost savings and space for lighter equipment). Lighter vehicles accelerate and decelerate faster, require less energy for acceleration, and wear less during deceleration. Weight savings at the top of the vehicle may also have an impact on the center of gravity of the vehicle. Weight reduction at the top of the vehicle can lower the entire center of gravity for the vehicle, resulting in a more stable vehicle along its roll axis. Further, heavy steel can require various engineering modifications such as reinforced areas (e.g., additional steel) for an extensible boom needed to reach remote areas. Such modifications can lead to large amounts of steel, which ultimately increase the weight of the vehicle and/or devices.

[0005] Some aerial boom systems have attempted to solve these problems by using aluminum to produce the aerial boom. However, in some situations it can be disadvantageous to use aluminum because aluminum is commonly extruded and easily deformable once welded. This can produce a need for more tolerance and/or expensive machining processes to bring a system back into tolerance once it has deformed. In addition, aluminum does not always maintain its strength and durability and can degrade under demanding operational conditions. For example, aluminum can begin to fatigue and lose strength and stiffness through overaging after being subjected to a 300 degree Fahrenheit temperature for over six hours.

[0006] In view of these problems, it would be desirable to provide an aerial boom assembly made from a lightweight, durable composite material. Additionally, it would be desirable to provide an aerial boom assembly that is easily configurable according to the particular needs associated with a given application. It would further be desirable to provide an aerial boom assembly that is able to maintain its strength and durability at high temperatures.

[0007] It would be advantageous to provide a system or the like of a type disclosed in the present application that provides any one or more of these or other advantageous features. The present invention further relates to various features and combinations of features shown and described in the disclosed embodiments. Other ways in which the objects and features of the disclosed embodiments are accomplished will be described in the following specification or will become apparent to those skilled in the art after they have read this specification. Such other ways are deemed to fall within the scope of the disclosed embodiments if they fall within the scope of the claims which follow.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] **FIG. 1** is a front perspective view of an aerial boom assembly coupled to a vehicle according to an exemplary embodiment.

[0009] **FIG. 2** is front perspective view of an aerial boom assembly in at least partially extended configuration according to an exemplary embodiment.

[0010] **FIG. 3** is an exploded front perspective view of the aerial boom assembly according to an exemplary embodiment.

[0011] **FIG. 4** is side view of the aerial boom assembly in an at least partially retracted configuration according to an exemplary embodiment.

[0012] **FIG. 5** is a front perspective view of the aerial boom assembly in an at least partially retracted configuration according to an exemplary embodiment.

[0013] **FIG. 6** is a rear perspective view of the aerial boom assembly in an at least partially extended configuration according to an exemplary embodiment.

[0014] **FIG. 7** is a rear perspective view of an aerial boom assembly in an at least partially extended configuration according to an exemplary embodiment.

[0015] **FIG. 8** is a perspective view of an exemplary embodiment of an aerial boom assembly, including a piercing nozzle assembly coupled to a drive train assembly and a turret nozzle.

[0016] **FIG. 9** is a side plan view of the aerial boom assembly illustrated in **FIG. 8**, illustrating one position of opposing actuators coupled to a drive wheel of the drive train assembly.

[0017] **FIG. 10** is a partial perspective view of the aerial boom attachment illustrated in **FIG. 9**.

[0018] **FIG. 11** is a perspective view of an exemplary embodiment of an aerial boom attachment without a turret nozzle.

[0019] **FIG. 12** is a perspective view of a piercing tool according to an exemplary embodiment.

[0020] **FIG. 13** is a side view of the piercing tool illustrated in **FIG. 12** according to an exemplary embodiment.

DETAILED DESCRIPTION

[0021] In general the aerial boom assembly described in this disclosure comprises a plurality of members, one of which is pivotally coupled to a mobile base (e.g., vehicle). The aerial boom assembly is configured for use with different vehicles including vehicle **100** shown in **FIG. 1**. Referring to **FIG. 1**, a front perspective view of vehicle **100** is shown according to an exemplary embodiment. Vehicle **100** may be of several different types and configured for several different uses. For example, vehicle **100** may be a fire-fighting vehicle or rescue vehicle configured to fight structural building fires and the like. Vehicle **100** may also be an airport rescue and fire-fighting vehicle (ARFF) or crash truck configured to fight aircraft fires, fuel fires, and the like. An exemplary application of an ARFF or crash truck is for it to be called upon in the event of an aircraft fire or crash at or near an airport.

[0022] Vehicle **100** includes a support structure **110**, a plurality of ground engaging motive members **120**, a power source, a vehicle body **140**, an aerial boom assembly **150**, and an aerial boom attachment **160** having a piercing nozzle assembly **170** (e.g., piercing tool). Support structure **110** has a front end **112** and a rear end **114**. Support structure **110** is generally configured to provide a structural support base for the various components of vehicle **100**.

[0023] Ground-engaging motive members **120** are coupled to support structure **110**. For purposes of this disclosure, the term "coupled" means the joining of two members directly or indirectly to one another. Such joining may be stationary in nature or movable in nature. Such joining may be achieved with the two members or the two members and any additional intermediate members being integrally formed as a single unitary body with one another or with the two members or the two members and any additional intermediate member being attached to one another. Such joining may be permanent in nature or alternatively may be removable or releasable in nature. By way of example, ground-engaging motive members **120** may be coupled to support structure **110** by a suspension system such that support structure **100** is supported relative to each ground engaging motive member. According to an exemplary embodiment, the suspension system is a modular independent suspension system including a coil spring suspension for steerable and non-steerable wheel assemblies and drive and non-drive axles. According to other exemplary embodiments, the suspension system may be any other suitable system (e.g., rigid axles and leaf spring suspension system).

[0024] Ground engaging motive members **120** include, for example, wheels (e.g., cast or machined and including rubber or composite tires, etc.), axle and wheel assemblies, or assemblies including articulated tracks (e.g., metal, rubber, composite, etc.), and the like which may be used to maintain support structure **110** above a surface and to allow vehicle **100** to move across the surface. Several configurations of ground engaging motive members **120** are possible (e.g., four, six and eight wheel arrangements, etc.), as commensurate with the type duty that will be experienced by vehicle **100**. For example, in the illustrated embodiment, ground engaging motive members **120** include at least two axle and wheel assemblies coupled to support structure **110**. A front axle and wheel assembly **122** is coupled to front end **112** of support structure **110**, and a rear axle and wheel assembly **124** is coupled to rear end **114** of support structure **110**. An optional intermediate axle and wheel assembly **126** is shown coupled to rear end **114** of support structure **110**, such that vehicle **100** has a six wheel configuration.

[0025] The power source may be mounted to support structure **110** and coupled to at least one of ground-engaging motive members **120** such that it may be driven by the power source. In other embodiments, the power source may be coupled to multiple ground engaging members, such as in an all-wheel drive system. According to an exemplary embodiment, the power source is an internal combustion engine, such as a gasoline or diesel engine. According to other exemplary embodiments, the power source may include a turbine engine, an electric motor, a hybrid-electric system, or the like.

[0026] Vehicle body **140** is coupled to support structure **110** and includes a front end **142**, and a rear end **144**. A vehicle cab **146**, including an operator station **148**, is typically disposed at front end **142** of vehicle body **140**. Any convenient and conventional materials may be utilized to form vehicle body **140**, such as steel, stainless steel, aluminum, or a composite material. Vehicle body **140** is configured to at least partially enclose a power source. Vehicle body **140** is also configured to at least partially house one or more fluid or chemical tanks (not shown) mounted to support structure **212**. Exemplary fluid tanks may include a water tank, a chemical flame-retardant tank, and the like.

[0027] According to an exemplary embodiment shown in **FIG. 1**, aerial boom assembly **150** is shown. Assembly **150** comprises a first member **152** pivotally coupled to vehicle **100** by way of mounting assembly **154**. First member **152** is coupled to aerial boom attachment **160** which is configured to couple to piercing nozzle assembly **170**. According to various exemplary embodiments, the first member may be fixed in length or alternatively may be adjustable in length. Further, the first member may comprise a telescopic configuration for extending and retracting in length. Furthermore, the first member may comprise one or more joints for pivotal movement. According to an exemplary embodiment, the assembly may comprise any number of members coupled together and/or to other objects according to any suitable arrangement. The aerial boom assembly may be composed of any suitable material having characteristics sufficient for the application. For example, the boom assembly may be composed of metal or a composite material, or a combination of both. Portions of the boom assembly may be raised and lowered by a plurality of hydraulic cylinder coupled to the assembly The hydraulic cylinders may be coupled to suitable and appropriate hydraulic control valves. According to an exemplary embodiment, assembly **150** may be replaced with boom assembly **210** described in conjunction with **FIGS. 2-7**.

[0028] A fluid source can be mounted directly on vehicle **100**, such as a fluid tank or chemical tank. The fluid source may also be an independent fluid source, such as a separate trailer structure, a separate tank vehicle, or a fixed fluid source, such as a lake, river, reservoir, tank, public or municipal utility source (e.g., a hydrant coupled to a pressurized fluid source), etc. The independent fluid source may be coupled to vehicle **100** for pumping purposes.

[0029] The fluid dispensing arrangement comprises a fluid source and a aerial boom attachment in fluid communication with the fluid source. Fluid communication may be made through a hose and reel assembly. The boom attachment will typically have a motion assembly associated with it for controlling the motion of the boom attachment in both the horizontal and vertical directions. The motion assembly can be controlled either manually or remotely from the vehicle depending on the particular circumstances in which the vehicle is being utilized. The motion assembly will typically include a motor, gears, and levers that will impart controlled motion to the nozzle assembly.

[0030] Fire-fighting equipment is typically controlled from operators station **148** within vehicle cab **146**. Fire fighting equipment may include, for example, a fluid dispensing nozzle, a video camera, a spotlight, a penetrating probe, and the like.

[0031] According to an exemplary embodiment shown in **FIGS. 2-7**, an aerial boom device or assembly **210** is shown pivotally coupled to a mobile base **212** (e.g., a vehicle, support structure, etc.). Assembly **210** comprises a first member **214** having a first end **216** and a second end **218**. Second end **218** is pivotally coupled to a mounting assembly **220** located on mobile base **212**. Assembly **210** further comprises a second member **222** pivotally coupled to first member **214** at first end **216**. Second member **222** comprises an extension member **224** movably coupled to second member **222** along an inner channel **226** of second member **222**. According to an exemplary embodiment, extension member **224** may couple to second member **222** according to a telescopic arrangement. For example, extension member **222** may be slidable outwardly and inwardly within second member **222**.

[0032] As shown in **FIGS. 2-7**, assembly **210** comprises a hydraulic mechanism **230** for controlling the movement of first member **214** and second member **222**. According to various exemplary embodiments, any suitable hydraulic system may be utilized to move the aerial boom assembly. Referring to **FIGS. 2-7**, hydraulic mechanism **230** comprises a first and second piston **232** and **234** which are each coupled to mobile base **212** and to first and second links **236** and **238**. First and second links **236** and **238** are coupled to first member **214**. Hydraulic mechanism **230** further comprises third and fourth pistons **240** and **242** coupled to first member **214** and to third and fourth links **244** and **246**. Third and fourth links are coupled to second member **222**. Hydraulic mechanism **230** further comprises fifth and sixth pistons **248** and **250** coupled to second member **222** and coupled to fifth and sixth links **252** and **254**. Fifth and sixth links **252** and **254** are coupled to extension member **224**. By controlling hydraulic mechanism **230**, an operator is able to position assembly **210** in a desired location. According to various alternative embodiments, the aerial boom assembly may have any number of suitable configurations. According to various exemplary embodiments, the hydraulic mechanism may be coupled to the vehicle components and members according to any suitable means including adhesive bonding, couplers, connectors, mechanical devices, etc.

[0033] According to an exemplary embodiment, corresponding components of the boom assembly are constructed from a composite material. A composite material is typically a combination of two or more materials that are chemically or mechanically joined at the interface to obtain specific properties that are not available from the individual constituents. According to an exemplary embodiment, the composite material comprises a reinforcement material in a polymeric matrix. The reinforcement will typically have a high strength and high stiffness coupled with a very low density. The reinforcement is chemically or mechanically joined to the matrix material producing an interface that enables a sharing and transfer of load among the composite constituent materials. The combination of reinforcement and matrix give the material a great deal of property tailorability for the application. The reinforcement can come in many forms including, but not limited to, PAN, cellulose, pitch based, or single or multiple wall nanotube carbon fiber. The fiber can be used as a tow (e.g., untwisted bundle of continuous filaments), tape, cross-stitched preform, knitted preform, random fiber mat, braided, truss core fabric preforms, or woven cloth with or without pre-applied matrix material (i.e., prepreg or dry fiber respectively). According to an exemplary embodiment, the reinforcement material may comprise any number of fibers of various volume fractions, and morphologies, in various orientations. The reinforcement could include metallic, carbon, polyester, polyethylene, aramid, nylon, ceramic, quartz, fiberglass, boron, combinations thereof, etc. In addition, hybrid reinforcement where fiber and particulate on a macro, micro, and nano scale are incorporated into the matrix to offer additional tailorability. The particulate may comprise any number of compositions, morphologies and orientations including, metallic, aluminum oxide, silicone carbide, titanium nitride, or combinations thereof, etc. According to an exemplary embodiment, the rigid matrix comprises any number of suitable resins or combination thereof such as thermoset, thermoplastic, polyester, vinyl ester, phenolic, epoxy, combinations thereof, etc. According to an exemplary embodiment, the composite material is a laminated composite which comprises sheets of continuous fiber material layered such that each sheet has the fiber material oriented in a given direction. According to a preferred embodiment, the composite material comprises a carbon fiber based core and a fiberglass coating.

[0034] There are many advantages to using composites for the aerial boom assembly and/or other components. For example, composites provide a higher tailorability for a given load case along with higher specific strength (e.g., as much as five times lighter than steel). This tends to reduce energy consumption as well as overall weight, wear, cost, etc. of other components of a system. Some composites are up to three times stiffer than steel. This helps reduce the deflection and deformation of the assembly under stress. The high strength of composite materials tends to help the assembly handle loads without breaking. Further, using composite materials can lead to fewer parts used in the assembly. Composites do not fatigue like steel, nor do they corrode or dent and have improved impact resistance. Furthermore, composites tend to have improved stability over steel under changing temperatures and are more flexible with respect to design needs (e.g., any aerial boom shape could be constructed to meet the particular needs of an application). The composite aerial boom assembly may be produced according to any suitable method. For example, the composite can be filament wound using prepreg or wet winding (e.g., using a monolithic mandrel), placed by hand, placed by a machine, etc. In addition, consolidation of the composite can take place using any suitable method. For example, the composite can be cured by autoclave, vacuum bag, etc. Other processes of manufacture are available such as a resin infusion processes, a resin film infusion processes including, but not limited to, vacuum assisted resin transfer molding (VARTM), SCRIMP™ (Siemens Composites Resin Infusion Molding Process), resin transfer molding (RTM), rubber assisted resin transfer molding (RARTM), SPRINT® etc.

[0035] As shown in **FIGS. 2-7**, assembly **210** is coupled to an aerial boom attachment **330** at end **228** of extension member **224**. According to an exemplary embodiment, attachment **330** may be pivotally coupled to the end of the extension member for controlled movement of a piercing nozzle assembly. According to various alternative embodiments, the aerial boom assembly may be coupled to any number of attachments/assemblies and may also be used without an attachment or assembly. According to an exemplary embodiment, a fluid dispensing mechanism may be coupled to the aerial boom assembly and attachment for dispensing fire retardant material and/or other liquids from the assembly.

[0036] **FIGS. 8 through 13** provide an exemplary embodiment of aerial boom attachment **330** for coupling to an aerial boom assembly. Aerial boom attachment **330** includes a frame assembly **332**, a drive train assembly **340** and a piercing nozzle assembly **360**.

[0037] According to an exemplary embodiment, frame assembly **332** is configured to couple to an aerial boom assembly. The frame assembly **332** can be coupled to the boom assembly by any convenient and suitable manner, for example, nuts and bolts, bands or straps, etc. The frame assembly **332** is composed of frame members **338** forming a lattice-type framework. The frame members **338** can be of any suitable geometric cross section, for example, angle beams, tubes, etc. and composed of any suitable material, such as steel, stainless steel, aluminum, composite material or a combination of such materials. The frame assembly **332** can be fabricated by individual parts conveniently fastened together with, for example, screws, bolts or welded or adhesives or it can be molded as a single piece. Several removable frame sections **336** are coupled to the frame members **338** for added stability. The removable frame sections **336** can be removed to provide access to components of the aerial boom attachment **330**, such as couplings, electrical connections and for maintenance work, etc. The center line of the frame assembly **334** is preferably axially aligned with the boom assembly.

[0038] The frame assembly **332** supports the drive train assembly **340** which is mounted on the frame assembly **332**. The drive train assembly **340** is axially aligned with the center line of the frame assembly **334** and parallel to the center line.

[0039] The drive train assembly includes a drive wheel **350** mounted on a rotational shaft **362**. The rotational shaft **362** is coupled to the frame assembly **332** with bearings **366**, such as pillow block bearings (see **FIG. 10**). The rotational shaft **362** is mounted on an axis **364** traverse to the center line of the frame assembly **334**. The rotational shaft **362** can be a hollow tube and can be coupled to the fluid supply or source **314** to route the fire retardant fluid.

[0040] The drive train assembly **334** includes two opposing actuators, a first actuator **342** and a second actuator **344**. The actuators **342**, **344** are configured so that one actuator moves in one direction and the other actuator moves in a proportionate opposite direction. The two actuators **342**, **344**, each have a drive pulley **346**, are coupled to the drive wheel **350** by a flexible linkage **348**. The flexible linkage **348** can be, for example, a cable, a chain, a belt, etc. It can also be multiple members or a single member. **FIGS. 8, 9** and **10** illustrate one exemplary embodiment of such arrangement.

[0041] The actuators **342, 344** can be fluid cylinders, for example, two-way hydraulic cylinders. As illustrated in **FIGS. 9 and 10**, when one cylinder retracts, the other cylinder extends by the same amount. Such movement exerts a force on the flexible linkage **348**, which in turn moves the drive wheel **350**. The actuators are arranged to allow the bore side of each actuator to be utilized. By using the bore side of the actuator, a higher retaining force can be achieved while keeping the cylinder size to a minimum. Control of the actuators **342, 344** is maintained from the cab of the vehicle.

[0042] The drive train assembly **340** can include an overload relief apparatus **352** integrated in each actuator **342**, **344**. The overload relief apparatus **352** can be, for example, a relief valve in the cylinder configured to dump the cylinder fluid to tank if a force on the cylinder exceeds a predetermined level. The overload relief apparatus **352** also functions to limit a vertical force on the piercing nozzle assembly **360** as will be explained below.

[0043] The piercing nozzle assembly **360** is coupled to the drive train assembly **340**. A manifold **368** is mounted on the drive wheel **350**. The piercing nozzle assembly **360** is configured for motion in one of the vertical and horizontal plane. In the vertical plane, the motion is provided by rotation of the drive wheel **350** and in the horizontal plane, the motion is provided by movement of the aerial boom assembly. A piercing tube **370** is mounted to the manifold. The piercing tube is hollow and is in fluid communication with the fluid supply **314** through the manifold **368**. A piercing nozzle **372** is mounted at the distal end of the piercing tube **370**. The piercing nozzle defines a plurality of orifices which allow the fire retardant fluid to pass through. A piercing tip **376** is mounted at the distal end of the piercing nozzle **372** and is configured to allow the tip to penetrate a structure to minimize or prevent the tip from slipping off at a low pierce angle. The piercing nozzle assembly **360** can operate within a predetermined range of positions relative to the center line of the frame assembly **334** and is configured to penetrate a structure even if the piercing nozzle assembly **360** is not in axial alignment with the center line of the frame assembly **334**.

[0044] As discussed above, the drive train assembly **340** with the opposing actuators **342, 344** and the overload relief apparatus **352** integral with the drive train assembly allow the penetrating nozzle assembly to operate at angles other than 90 degrees to the structure to be penetrated. Once the piercing tip **376** is positioned, as the aerial boom assembly pushes the piercing tube **370** into the structure, the opposing actuators **342, 344** operate to lock the piercing tip **376** into position. The overload relief apparatus **352** relief valves are calibrated to allow a piercing tip movement until just before the piercing tip fails as determined by the manufacturer of the aerial boom attachment **330**.

[**0045**] Another embodiment of the aerial boom attachment **330** includes an electronic control system **390** (see **FIG. 9**) coupled to the drive train assembly **340** on the piercing nozzle assembly **360**. The electronic control system **390** is coupled to a first position sensor **392** associated with the drive train assembly **340** and a second position sensor **394** associated with the piercing nozzle assembly **360**. The position sensors **392, 394** generate a signal corresponding to the relative positions of the drive train assembly **340** and the piercing nozzle assembly **360** indexed to the boom position. The sensors can be linear encoders or similar devices mounted in the actuators **342, 344** which allow constant position sensing. In the event that the vertical force exerted on the piercing nozzle assembly exceeds the limits set on the overload relief apparatus **352** the overload relief apparatus will allow the actuator to move as the boom continues to exert a force. The movement of the actuator in turn moves the driver wheel **350** thereby moving the piercing tube **370** to prevent damage. The position sensors **392, 394** allow the operator to know the position of the piercing tube **370** and reset the piercing nozzle assembly **360** from within the cab by manipulating the actuators **342, 344** to again properly align the piercing tube **370** for penetration of a structure.

[**0046**] Another embodiment of the aerial boom attachment includes a turret nozzle **380** which is mounted on the frame assembly **332** and is in fluid communication with the fluid supply **314**. The turret nozzle **380** is configured to rotate 90 degrees to either side of the center line of the frame assembly **334** and 90 degrees in a vertical plane. The turret nozzle **380** can also be configured to rotate 20 degrees above the center line of the frame assembly **334** and 70 degrees below the center line of the frame assembly **334**. The turret nozzle **380** has an independent drive mechanism for moving the turret nozzle as directed by an operator and is provided with position sensors which generate a signal informing the operator as to the orientation of the turret nozzle.

[**0047**] The piercing nozzle assembly is capable of rotating 360 degrees in the vertical plane, 180 degrees above the plane of the boom assembly and 180 degrees below the plane of the boom assembly. The piercing nozzle assembly **360** and the turret nozzle **380** can be coupled independently to the fluid supply **314** or they can be coupled through a common conduit through a diverting valve to direct the flowable fire retardant to either the turret nozzle **380** or the piercing nozzle assembly **360**.

[**0048**] The piercing tube **370**, piercing nozzle **372** and piercing tip **376** can be interchangeable to accommodate various dimensions as determined by an operator. The overload relief (e.g., protection) apparatus **352** can be adjusted to accommodate the various dimensions of the interchangeable piercing tube, piercing nozzle **372** and piercing tip **376** due to its dimension and material characteristics and to set a maximum allowable force traverse to the axis of the piercing tube without failure of the piercing tube. It should be understood that the drive train assembly **340** moves the piercing nozzle assembly as determined by an operator, however, that the force exerted on the piercing nozzle assembly **360**, and particularly the piercing tube **370** through the piercing tip **376** will also move the actuators **342, 344** as the aerial boom assembly pushes the piercing nozzle tip **376** into the structure. The position sensors **392, 394** associated with the actuators **342, 344** provide a signal to the electronic control system **390** thereby allowing the operator to monitor the position of the piercing apparatus and maintain its calibration and index relative to the boom position. Since different piercing tip assemblies are available and interchangeable, the maximum angles at which the piercing tip can penetrate a structure without failure will vary between individual tip designs. Adjusting for such characteristics can be affected through changes in the overload relief apparatus **352** and the type of actuators **342, 344** utilized in the drive train assembly **340**.

[**0049**] Piercing nozzle assembly **360** is coupled to end **228** of boom assembly **210** and typically includes an aerial boom attachment **330**, a piercing nozzle **372** coupled to aerial boom attachment **330**, and a piercing tube **370** coupled to piercing nozzle **372**. The aerial boom attachment **330** is configured to control the motion of piercing nozzle assembly **360** in both the horizontal and vertical directions. Aerial boom attachment **330** can be controlled either manually or remotely from the vehicle (e.g., using an operator station) depending on the particular circumstances in which the vehicle is being utilized. Piercing nozzle **372** is typically coupled to a fluid source **314** and is shaped as a frustum with a hollow passage therein and includes a plurality of openings configured to dispense a pressurized fluid or other material from the fluid source. The interchangeable piercing tool **374** is generally configured to penetrate a structure so that piercing nozzle assembly **60** may dispense the pressurized fluid or other material inside the structures.

[**0050**] The fluid source **314** can be mounted directly on the vehicle, such as a fluid tank or chemical tank. The fluid source may also be an independent fluid source, such as a separate trailer structure, a separate tank vehicle, or a fixed fluid source, such as a lake, river, reservoir, tank, public or municipal utility source (e.g., a hydrant coupled to a pressurized fluid source), etc. The independent fluid source may be coupled to the vehicle for pumping purposes.

[**0051**] **FIGS. 12 and 13** illustrate an exemplary embodiment of a piercing tool **470** (e.g., piercing nozzle assembly, piercing device, etc.). Piercing tool **470** includes a member **472** having an end **474** and an end **476**. Piercing tool **470** is generally configured to penetrate a wall of a structure, such as a building or an airplane fuselage, so that a flame-retardant fluid or material may be dispensed within the structure by a piercing nozzle assembly during fire-fighting and rescue operations. More specifically, piercing tool **470** is configured to penetrate a structure such as a building or an airplane fuselage from a number of different angles without requiring a significantly high degree of perpendicular alignment with the surface of the structure.

[**0052**] End **474** includes a cutting edge **478** formed by the intersection of a first surface **480** and a second surface **482** and configured to facilitate the penetration of a structure from a number of different angles without requiring a significantly high degree of perpendicular alignment with the surface of the structure. Cutting edge **478** may have a variety of different configurations depending upon the shape of the intersection of the first surface **480** and the second surface **482**. For example, in the illustrated embodiment, the intersection of the first surface **480** and the second surface **482** is circular in shape, which provides an annular cutting edge **478**. According to other embodiments, cutting edge **478** is configured as other shapes, such as other elliptical shapes, ovular shapes, many-sided shapes, etc. Cutting edge **478** may have also variety of different configurations depending upon the orientation of the intersection of the first surface **480** and the second surface **482**. For example, in the illustrated embodiment, surface **480** and surface **482** intersect in a plane **486** according to an angle θ such that plane **486** is substantially perpendicular to a longitudinal axis **488** of member **472**. According to other exemplary embodiments, different angles and planes of intersection are used to define cutting edge **478**.

[**0053**] First surface **480** is a tapered outer surface of member **472**, with the surface tapering toward end **474** such that end **474** is narrower in width or diameter than end **476**. Surface **480** may be a number of different shapes. For example, in the illustrated embodiment, Surface **480** has the shape of an elliptical frustum having a circular cross section. Other exemplary shapes of surface **480** include frustums or other tapered extrusions having ovular, egg-shaped, or many-sided cross sections, etc.

[**0054**] Second surface **482** defines a cavity **484** within member **472**. Second surface **482** and cavity **484** may be a number of different shapes. For example, in the illustrated embodiment, surface **482** is a concave surface such that cavity **484** is shaped as a section of a sphere. Other exemplary configurations of surface **482** and cavity **484** include frustums, conics, cylinders, etc.

[**0055**] End **476** is configured to facilitate the coupling of piercing tool **470** to piercing nozzle assembly **360** shown in **FIGS. 8 and 11**. Any common means of attachment, such as welding, brazing, interlocking configurations, etc., may by used to couple piercing tool **470** to piercing nozzle assembly **360**. For example, in the illustrated embodiment, end **476** includes screw-type mating threads **490** for removably coupling piercing tool **470** to piercing nozzle assembly **360** so that piercing tool **470** may be replaced if, for example, it breaks or becomes dull.

[**0056**] Piercing tool **470** may be formed from various different materials. According to an exemplary embodiment, piercing tool **470** is formed from a durable rigid material. For example, piercing tool **470** may be made from metal, alloys, steel, stainless steel, composites, etc. In addition, according to various other embodiments, piercing tool **470** is optionally coated or plated with a material such as chrome, or heat treated or plated with a hardened coating such as tungsten carbide for wear and corrosion resistance.

[**0057**] Piercing tool **470** may have varying overall size and dimensions based on, for example, the particular piercing application, the thickness and material of the structure to be pierced, the strength of the components to which piercing tool **470** is attached, etc. For example, according to an exemplary embodiment, piercing device **470** is configured to penetrate an aluminum aircraft fuselage and has a length **492** of approximately four inches, a width or diameter **494** of end **474** of approximately three quarters of an inch, a width or diameter **496** of end **476** of approximately one quarter of an inch, and a depth **498** of cavity **484** of approximately one eighth of an inch. According to other exemplary embodiments, these dimensions are varied as applicable.

[**0058**] It is also contemplated that additional tools and apparatus can be mounted on the aerial boom attachment that is appropriate for a given application such as for instance, a video camera, for example, an infrared video camera, a spot or search light, a hose and reel assembly, hydraulic actuated jaws for manipulating metal or such other appropriate tool for use with an aerial boom attachment. Additional modifications will be evident to those with ordinary skill in the art.

[**0059**] It is important to note that the above-described embodiments are illustrative only. Although the assembly has been described in conjunction with specific embodiments thereof, those skilled in the art will appreciate that numerous modifications are possible without materially departing from the novel teachings and advantages of the subject matter described herein. For example, different types of devices and assemblies may be used in addition to or instead of the those described herein. Accordingly, these and all other such modifications are intended to be included within the scope of the appended claims. The order or sequence of any process or method steps may be varied or re-sequenced according to alternative embodiments. In the claims, any means-plus-function clause is intended to cover the structures described herein as performing the recited function and not only structural equivalents but also equivalent structures. Other substitutions, modifications, changes and omissions may be made in the design, operating conditions and arrangements of the preferred and other exemplary embodiments without departing from the scope of the appended claims.

What is claimed is:

1. An aerial boom assembly comprising:

a first member having a fixed length and comprising first and second ends, the second end being pivotally coupled to a mobile base;

a second member pivotally coupled to the first member at the first end, the second member comprising an extension member slidably coupled to the second member along an inner channel of the second member;

wherein at least one of the first and second members are made from a composite material comprising a reinforcement material in a polymeric matrix.

2. The assembly of claim 1, wherein the reinforcement material is joined to the matrix material to produce an interface that enables sharing and transfer of load among composite constituent materials.

3. The assembly of claim 1, wherein the reinforcement material is at least one of chemically and mechanically joined to the matrix material.

4. The assembly of claim 1, wherein the reinforcement material comprises at least one of PAN, cellulose, pitch based nanotube carbon fiber, single or multiple wall nanotube carbon fiber, or combinations thereof.

5. The assembly of claim 1, wherein the reinforcement material comprises at least one of an untwisted bundle of continuous filaments, tape, cross-stitched preform, knitted preform, random fiber mat, braids, truss core fabric preforms, woven cloth with a pre-applied matrix material, woven cloth without a pre-applied matrix material, or combinations thereof.

6. The assembly of claim 1, wherein the reinforcement material comprises at least one of a metal, carbon, polyester, polyethylene, aramid, nylon, ceramic, quartz, fiberglass, boron, or combinations thereof.

7. The assembly of claim 1, wherein the composite material is a laminated composite.

8. The assembly of claim 7, wherein the laminated composite comprises sheets of continuous fiber material layered such that each sheet has the fiber material oriented in a given direction.

9. The assembly of claim 1, wherein the matrix comprises a resin.

10. The assembly of claim 9, wherein the resin comprises at least one of a thermoset, thermoplastic, polyester, vinyl ester, phenolic, epoxy, or combinations thereof.

11. The assembly of claim 1, wherein the mobile base comprises at least one of a fire fighting vehicle, a rescue vehicle, a crash vehicle, and a work vehicle.

12. The assembly of claim 11, further comprising a hollow piercing mechanism coupled to the extension member.

13. The assembly of claim 12, wherein the second member comprises a telescoping arrangement for slidably coupling the extension member to the second member.

14. The assembly of claim 13, further comprising a hydraulic mechanism for pivoting the first and second members and sliding the extension member.

15. The assembly of claim 14, wherein the hydraulic mechanism comprises first and second pistons coupled to the mobile base and coupled to first and second links, the first and second links being coupled to the first member.

16. The assembly of claim 15, wherein the hydraulic mechanism further comprises third and fourth pistons coupled to the first member and coupled to third and fourth links, the third and fourth links being coupled to the second member.

17. The assembly of claim 16, wherein the hydraulic mechanism further comprises fifth and sixth pistons coupled to the second member and coupled to fifth and sixth links, the fifth and sixth links being coupled to the extension member.

18. The assembly of claim 17, further comprising a fluid dispensing mechanism.

19. The assembly of claim 1, wherein the composite material comprises a carbon fiber based core and a fiberglass coating.

20. A vehicle for firefighting and rescue operations, comprising:

a support structure having a support surface;

a plurality of wheels coupled to the support structure, wherein the wheels maintain the support structure above a surface;

a power source for powering the vehicle; and

an aerial boom assembly coupled to the support surface, the aerial boom assembly being made from a composite material comprising a reinforcement material suspended in a polymeric matrix.

21. The vehicle of claim 20, further comprising a hollow piercing mechanism coupled to the aerial boom assembly.

22. The vehicle of claim 21, wherein the aerial boom assembly comprises first and second members pivotally coupled together.

23. The vehicle of claim 22, wherein the first member of the aerial boom has a fixed length and comprises first and second ends, the second end being pivotally coupled to the support surface.

24. The vehicle of claim 23, wherein the second member comprises an extension member coupled to the second member by way of a telescopic arrangement.

25. The vehicle of claim 24, wherein the telescopic arrangement comprises slidably coupling the extension member to the second member so that the extension member is able to move within an inner portion of the second member.

26. The vehicle of claim 25, further comprising a hydraulic mechanism for moving the aerial boom assembly.

27. The vehicle of claim 20, wherein the matrix comprises a resin.

28. The vehicle of claim 27, wherein the resin comprises at least one of a thermoset, thermoplastic, polyester, vinyl ester, phenolic, epoxy, or combinations thereof.

29. The vehicle of claim 28, wherein the reinforcement material comprises at least one of metal, carbon, polyester, polyethylene, aramid, nylon, ceramic, quartz, fiberglass, boron, or combinations thereof.

30. A method for producing an aerial boom assembly, comprising:

providing a first member having a fixed length and comprising first and second ends, the second end being pivotally coupled to a vehicle;

providing a second member pivotally coupled to the first member at the first end, wherein the second member comprises an extension member coupled to the second member by way of a telescopic arrangement; and

producing the first and second members from a composite material utilizing a reinforcement material in a polymeric matrix.

31. The method of claim 30, further comprising producing the polymeric matrix from at least one of a thermoset, thermoplastic, polyester, vinyl ester, phenolic, epoxy, or combinations thereof.

32. The method of claim 31, further comprising producing the reinforcement material from at least one of metal, carbon, polyester, polyethylene, aramid, nylon, ceramic, quartz, fiberglass, boron, or combinations thereof.

33. The method of claim 32, wherein the vehicle is at least one of a firefighting vehicle, a rescue vehicle, a crash vehicle, and a work vehicle.

34. The method of claim 33, further comprising providing a hollow piercing mechanism coupled to the extension member.

35. The method of claim 34, further comprising configuring the telescopic arrangement so that the extension member is slidably coupled to the extension member and the extension member is able to move within an inner portion of the second member.

36. The method of claim 35, further comprising providing a hydraulic mechanism for moving the aerial boom assembly.

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