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(54) DISPOSAL ROBOT AND ROBOTIC SYSTEM ASSEMBLY FOR DISPOSAL OF DISPOSAL CASKS IN A DEEP GEOLOGICAL REPOSITORY

(57) The proposed solution is a robotic system assembly for disposal of disposal casks (3) in the deep geological repository (5) including a system of underground corridor structures and boreholes with the railway transport network (2) with trolley wires, and a disposal robot (36) of a robotic system for disposal of disposal casks (3) in the deep geological repository (5) as its main parts designed to implement the process of transport, manipulation, disposal and backfilling of disposal casks (3) with spent nuclear fuel into the underground horizontal or subhorizontal boreholes of deep geological repository (5).

Robotic system assembly (1) installed in a deep geological repository (5) is provided as its basic element with a disposal robot (36) of a robotic system for disposal of disposal casks (3) in the deep geological repository (5), where the starting point of the disposal robot (36) is a vehicle (30) with turntable - conveyance vehicle of the disposal robot, and further it is equipped with a conveyance vehicle (6) for transport of bentonite fillings (4) and disposal casks (3).

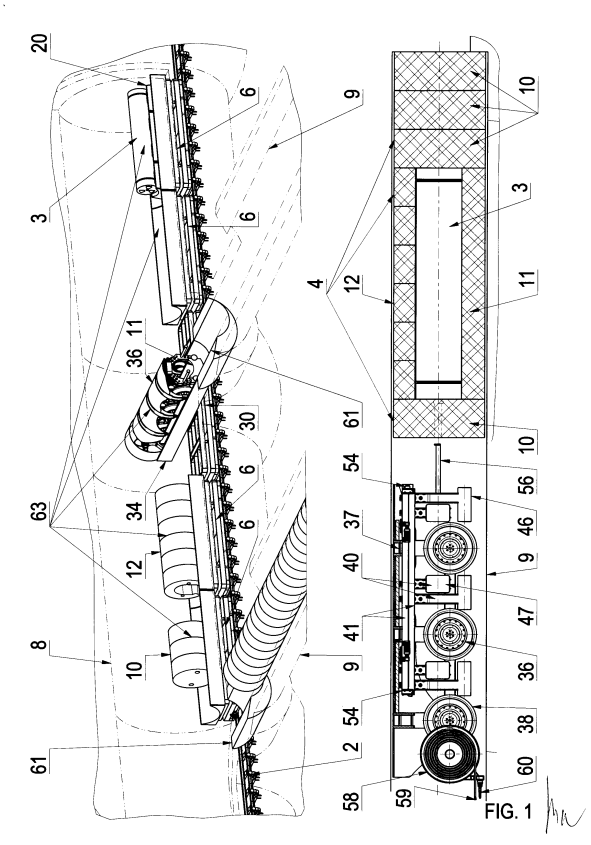

FIG. 1

EP 3 407 360 A1

Description

TECHNICAL FIELD

[0001] The invention relates to the field of disposal, transport and manipulation of disposal casks with spent nuclear fuel in an underground system of a deep geological repository equipped with robotic technologies.

BACKGROUND ART

[0002] At present, none of the world's project developers of deep geological repositories of disposal casks with spent nuclear fuel has not yet designed or realized a technology according to the invention - a multifunctional robotic system - super-robot, with the ability to associate diametrically different robotic processes in one robotic technology - process of transport, manipulation, disposal and backfilling of disposal casks with spent nuclear fuel into the underground horizontal or subhorizontal disposal boreholes of deep geological repository. Upon the comparative analyses of the proposed solution according to the invention with concepts of analogous technologies in ongoing or planned projects of deep geological repository in Europe and in the world, it is demonstrable that there is no transport, handling, disposal and backfilling fully robotic technological system used, which would be close to the proposed solution according to the invention. The closest solution to the proposed project is a disposal concept of Swiss society Nagra which also proposes a disposal system of disposal casks with spent nuclear fuel into the horizontal tunnels where in one half of the space profile of the tunnel there is a disposal cask transported in a protective casing from which it is pushed by a hydraulic cylinder onto the shaped bed in front of the casing from which it is then, still in the horizontal position, transported by a gripper manipulator into the area of the second half of the tunnel profile onto the shaped bentonite bed which is already placed in the filling robot. The filling robot then returns to the base area, where it must be transformed to another track and interchanged for an injection robot which then freely, by the bulk bentonite, backfills the space between the profile of the disposal tunnel and the outer shell of the disposal cask with spent nuclear fuel.

[0003] The proposed concept according to the invention solves the disposal process unto the disposal borehole though a fully robotized multifunctional system - super-robot, which without the intervention of a human agent solves the complex end manipulation transport, disposal and backfilling process, which diametrically different parameters and functions are accumulated in one robotic system which creates a unique world novel technology, oriented on the project program Industry 4.0, in a partial manner. The proposed solution has not only unrivaled technological and utility added value but also an extremely high economic added value compared to other current methods and technologies.

DISCLOSURE OF THE INVENTION

[0004] The above-mentioned disadvantages are solved by a disposal robot of a robotic system for disposal of disposal casks in the deep geological repository and a robotic system assembly for disposal of disposal casks in the deep geological repository including a system of underground constructions of corridor and boreholes with the rail transport network, serving as an environmentally acceptable method of disposal of nuclear waste, the main part of which is the disposal robot of the robotic system for disposal of disposal casks in the deep geological repository.

[0005] The principle of the disposal robot of the robotic system is in a fact that it is formed by a basic part which is a vaulted frame in which lower longitudinal girders, there are shaped wheels with in-wheel drives arranged in the cones in overhung manner;

where in the inner space of the vaulted frame, there is a dual effector is attached in a horizontal planar frame suspended on two pairs of vertical motion screws of the same orientation and the same pitch, firmly fixed in the upper girder of the vaulted frame through gear wheels with nut which are arranged in radiaxial bearings in the planar frame; while each pair of the gear wheels with nut is driven by a rotary drive with pinion through a flexible closed element; while both rotary drives with pinion are part of the planar frame, and both rotary drives with pinion are mutually electronically synchronized;

while the dual effector is suspended under the planar frame, while it is further provided with two longitudinal lateral rows of eyes of pendulum bearing of an effector for manipulation with bentonite fillings, and eyes of bearing of an effector for manipulation with disposal casks;

where on the other, the effector for manipulation with bentonite fillings is formed by a round rod with swivel collets of bentonite bed, ended by cylindrical large contact grips, and the effector for manipulation with disposal casks is made so that on the round rod, there is arranged in swinging manner a hollow rod with swivel collets of disposal casks ended by shaped large contact grips;

while both lateral parallel pairs of concentric round rods and hollow rods are synchronized by two front-end pairs of toothed segments and driven by linear actuators attached always either on the swivel collet of bentonite bed, or on the swivel collet of disposal casks, and on the opposite side in the eye of the planar frame; while fitted pins are constrained in the frontal areas of the front swivel collets of bentonite bed;

while in the rear part of the vaulted frame, there is a frame superstructure in which a winding drum of the power and control cable ended by a connecting plug is arranged, while further in the rear part of the vault frame being firmly connected to it, there is a safety hook of mechanical connection of the disposal robotic vehicle and the vehicle with turntable.

[0006] A preferred solution is when the shaped wheels with in-wheel drives include a planetary gearbox.

[0007] The principle of the robotic system assembly for disposal of disposal casks in the deep geological repository, the main part of which is the disposal robot for disposal of casks in the deep geological repository, is that it comprises the system of structures of horizontal corridors at the beginning of which there is an access corridor on which the structures of the technological corridor link up, which are linked up perpendicularly at a certain height above the floor by the structures of horizontal corridors of the structures of rectangular disposal boreholes for central disposal of disposal casks with lining through spatially pressed bentonite fillings;
while the robotic system assembly is further equipped with the disposal robot of the robotic system robot for disposal of disposal casks in the deep geological repository;
where the starting point of the disposal robot is the vehicle with turntable which has an extended vehicle frame in which electronically synchronized tailstock sleeves are stored, while the retractable parts of the electronically synchronized tailstock sleeves are firmly connected with an extended superstructure frame in which axis there is a turntable with drive which is connected through a flange with a rotatable superstructure on which rear part there is a rope winch with transmission roller stored in the extension;
when in the entrance part of the construction of each disposal borehole, there is built a borehole offset creating a crossing of the disposal robot between the vehicle with turntable and the disposal borehole with a difference in link-up of travelling areas;
while the robotic system assembly is further equipped with a conveyance vehicle for transport of bentonite filling and disposal casks, which is made up of the vehicle frame in which electronically synchronized retractable tailstock sleeves are stored; while in the front-end front parts of the conveyance vehicle, there are mounted through vertical pins the couplings with controlled locking and limited swing within the storage pocket;
where the hoisted superstructure frame with casings with locking is arranged on the retractable tailstock sleeves, where through the part of each vehicle frame, there is a concave superstructure with opening above the casings with locking firmly connected with it, while the inner diameter of the concave superstructure corresponds to the dimensional diameter of the disposal borehole construction; while a stand with fixation for transport of disposal cask is placed in the conveyance vehicle; while in the spatial stand structure lined with supporting parts, there is the fixation mechanism built-in consisting of mechanism drive, where the drive consists of rotary motor, followed by the countershaft distribution gearbox, next to which there are two opposite branches each of which comprises a power gearbox in the outset, its output is followed by a distribution shaft to control the larger lever of the four-articulated mechanism, while a smaller lever of four-articulated mechanism is also part of a side shaft with retaining arms.

[0008] Furthermore, it is advantageous if the borehole constructions are circular in cross-section.

[0009] Furthermore, it is advantageous if the bentonite fillings are circular bentonite fillings, bentonite beds and circular bentonite blocks.

[0010] Furthermore, it is advantageous if the circular bentonite fillings and circular bentonite blocks have openings with inner offset.

[0011] Furthermore, it is advantageous if the conveyance vehicles and vehicles with turntable forms the set of robotic vehicles.

[0012] Furthermore, it is advantageous if the set of robotic vehicles is formed by a set of four conveyance vehicles, the first of which is equipped with the stand with fixation and furthermore with the vehicle with turntable and disposal robot.

[0013] Furthermore, it is advantageous if all vehicles forming the sets of robotic vehicles are connected through the coupling with controlled locking.

[0014] The advantage of the proposed solution is that the designed robotic technology of disposal of disposal cask into the horizontal boreholes eliminates completely all sliding movements of the disposal cask on the ground. The disposal cask with spent nuclear fuel is not pushed into the disposal place in the borehole but it is transferred and laid down gently. This method is very careful to the surface of the disposal cask and less energy consuming. Another advantage of the proposed solution is the minimized manipulation with disposal casks in vertical direction which is very energy-efficient. Another unquestionable advantage is the simplicity of the entire robotic process, resulting in minimizing the number of special single-purpose machines and devices which are needed for realization of storage of disposal casks with spent nuclear fuel and bentonite prefabricated parts.

BRIEF DESCRIPTION OF DRAWINGS

[0015] On the attached sheets, there are shown figures of examples of realization of the robot of the robotic system for disposal of disposal casks in the deep geological repository, and the robotic system assembly for disposal of disposal casks in the deep geological repository.

FIG. 1: On the top, axonometric view, there is prepared the complete loaded set of robotic vehicles in front of the disposal borehole, and on the bottom figure, there is cross-section of the disposal borehole and disposal robot. In the disposal borehole, there are shown the first three circular bentonite fillings placed by a special procedure, then each of the disposal cask is stored cyclically, a centrally located disposal cask is shown here under which a bentonite bed is at first deposited, the space around them is filled with circular bentonite block, and the disposal cycle is finished by blanking with circular bentonite fillings. The disposal robot is in the phase when it filled one of the circular bentonite fillings.

FIG. 1.1: Detailed axonometric view of the vehicle with turntable when the rotatable superstructure is together with the disposal robot thereon in position when it is prepared to load the held bentonite bed through the effector for manipulation with bentonite bed. This is the first part that is loaded into the borehole.

FIG. 1.2: Detailed sectional view of the disposal robot where the connection between the function of the fitted pin and the opening with inner offset is evident, during manipulation with circular bentonite blocks and fillings. On the disposal robot, there are its main subassemblies well visible, which are: vaulted frame, dual effector, shaped wheels with in-wheel drives, and winding drum of the power and control cable.

FIG. 2: Overall view of the deep geological repository where is the railway network with trolley wires and rail turntables. The figure in axonometric view shows the preparatory phase of alignment of loaded conveyance vehicles and a method of arrangement of the vehicle with turntable with disposal robot into the set of robotic vehicles.

FIG. 3: Here are shown three stages of emptying of the set of robotic vehicles. In the upper axonometric view, the set of robotic vehicles is in the arrival phase in front of the borehole. In the middle view, there is the phase when the robotic vehicle had already taken the bentonite bed from the second conveyance vehicle, returned and picks up the disposal cask for its placement on bentonite bed in the disposal borehole. These operations are associated with travels of the disposal robot on the superstructures of conveyance vehicles and turning of the disposal robot of 90° by the rotatable superstructure of the vehicle with turntable, which is shown on the bottom view, when the disposal robot is ready to ride with the disposal cask into the disposal borehole after rotating the rotatable superstructure by 90°.

FIG. 4: The axonometric view shows the conveyance vehicle into which superstructure the stand with fixation is inserted, and thereon a disposal cask is laid in the horizontal position, held by the fixation mechanism for safety reasons.

FIG. 4.1: On the top view, there is a cross section of the conveyance vehicle with a detailed view of the retractable tailstock sleeves shown. On the bottom view, there is a cross section of the inserted stand with fixation, where the connection between the stand structure with fixation elements, superstructure frame and vehicle superstructure is visible; the section further passes through the fixation mechanism acting through the side shafts with retaining arms on the disposal casks.

FIG. 5: The axonometric view of the vehicle with turntable is shown on the figure, when its rotatable superstructure is rotated by 90°, and the disposal robot with disposal cask gripped by the effector for manipulation with disposal casks is ready for entering the disposal borehole.

FIG. 5.1: On the top view, there is a cross section of the vehicle with turntable over the retractable tailstock sleeves, while the retractable tailstock sleeves allow lifting of the superstructure frames and thus the superstructures where the necessary parts for backfilling the disposal borehole. The height adjustment of the entire set of robotic vehicles allows smooth passage of the disposal robot into the disposal borehole in front of the borehole offset. On the bottom view, there is lengthwise section of the vehicle with turntable and disposal robot. An accumulator pack can be arranged in the extended frame of the vehicle with turntable, as an alternative to power supply of the vehicle with turntable and disposal robot. The couplings with controlled uncoupling are evident in the front-end heads of the vehicle with turntable, including their placing in vertical pins and storage pockets.

FIG. 6: On two axonometric views, there is the fixation mechanism which is part of the stand with fixation, and furthermore on the bottom view there is a structure lined with supporting parts with two assembling pins fitting in the lower part into the casings with locking of the superstructure frame. On the top view, there is only the fixation mechanism, and there is a drive visible comprising rotary motor, countershaft distribution gear, which are followed by two synchronized branches represented by the distribution shafts controlling the four-articulated mechanism on each side, and each four-articulated mechanism controls one of the side shafts with retaining arms. On the bottom view, there is the fixation mechanism visible, inserted in the stand with fixation, in which space it is folded in the initial position.

FIG. 6.1: On two views, there are sections of the stand with fixation and inserted fixation mechanism. On the top section, there is the stand with fixation in operational position when it retains the disposal cask. On the bottom figure, there is the fixation mechanism in initial position visible, in which it is folded within the volume of the structure lined with supporting parts

FIG. 7: On the bottom view, there is section of the disposal robot. There is the vaulted frame as a robot carrying part, suspension of the gripping dual effector on the motion screws through the horizontal pla-

nar frame. Furthermore, there are shaped wheels with alternative planetary gearboxes - see the detail bottom right. In the front space of the disposal robot, there are fitted pins for manipulation with circular bentonite filling constrained in the swivel collets of bentonite bed. In detail, at the bottom of the figure on the left, there are in detail the vertical motion screws on which the gear wheels with nuts are screwed, and they are driven by rotary drive with pinion through the flexible closed element. At the front, there is located one of the pairs of toothed segments which synchronizes the lateral swivel collets either of the bentonite bed or disposal casks.

FIG. 7.1: On the front axonometric view of the disposal robot, there is the dual effector highlighted, including the lifting mechanism using synchronized pairs of motion screws. Both effectors inset to each other, with swivel collets are well visible, and there are visible the large contact grips in particular: cylindrical - for gripping a bentonite bed, and shaped - for fixation of a disposal cask.

FIG. 7.2: On the rear axonometric view of the disposal robot, where the vaulted frame without cover sheets is evident, where in the rear part, there is the frame superstructure into which there is inserted the winding drum of the power and control cable ended by a connecting plug and a hook is connected firmly thereto for safety pulling out the disposal robot via the rope winch that is placed in the rear part of the rotatable superstructure of the disposal robot.

FIG. 8: Section of the disposal robot is on the figure. There is the dual effector shown, which supporting part is the vaulted frame in which hinged on the drive screws is the planar frame as a supporting part of the dual effector including the effector for manipulation of bentonite fillings which swivel collets synchronize the circular rods and hollow rods of control of the swivel collets, and they are the basis of the effector for manipulation of disposal casks. Furthermore, there are visible the linear actuators attached on the planar frame, as a source of motion of both effectors. In the middle of the view, there is the winding drum od the power and control cable in the rear part of the disposal robot.

BEST MODE FOR CARRYING OUT THE INVENTION

[0016] Robotic system 1 of disposal of disposal casks in the deep geological repository includes underground system of corridors and boreholes with railway network 2 with trolley wires for an environmentally acceptable way of disposal of nuclear waste.

[0017] The entrance to this system is an inclined access tunnel through which by the wheel transport with the load of disposal casks 3, including pressed bentonite filling 4 are transported into the deep geological repository 5, where they will be translated in the respective numbers onto driven conveyance vehicles 6 with superstructures 19 for transport of the required load.

[0018] The deep geological repository 5 consists of a system of horizontal corridor constructions at the beginning of which there is the access corridor 7 on which the constructions 8 of technological corridors link up, which are linked up perpendicularly at a certain height above the floor by the constructions of horizontal corridors of the rectangular, circular in cross-section, constructions 9 of disposal boreholes of necessary lengths.

[0019] Constructions 9 of disposal boreholes, representing a substantial part of the deep geological repository 5, serve for disposal of disposal casks 3 which preparation including filling takes place in the surface robotic workplace. Disposal casks 3 are transported into the constructions 9 of disposal boreholes, where they are stored centrally, where they are lined with space-pressed bentonite fillings 4 of three types: circular bentonite fillings 10, bentonite beds 11 and circular bentonite blocks 12.

[0020] The circular bentonite fillings 10 and circular bentonite blocks 12 are provided with holes 13 with inner recess.

[0021] The conveyance vehicle 6 is driven, its base is formed by the vehicle frame 14, into which the electronically synchronized retractable tailstock sleeves 15 are compiled, and the couplings 16 with controlled uncoupling with limited swing within the storage pocket are attached through vertical pins in front-end heads.

[0022] The superstructure frame 17 with storage casings 18 with locking is arranged on the retractable tailstock sleeves 15. Part of each vehicle frame 14 is the concave superstructure 19 with openings, firmly connected with it, above the storage casings 18 with locking. Inner diameter of the concave superstructure 19 corresponds to the diameter of the construction 9 of disposal borehole.

[0023] Designated for transfer of disposal cask 3, built-in in the conveyance vehicle 6, there is the stand 20 with fixation into which spatial structure 21 lined with supporting parts, there is embedded the fixation mechanism 22 consisting of mechanism drive 23, where the mechanism drive 23 comprises the rotary motor 24, then follows the countershaft distribution gearbox 25, followed by two opposite branches each of which include the power gearbox 26 in the outset, its output is followed by the distribution shaft 27 which controls the larger lever of the four-articulated mechanism 28, while the smaller lever of four-articulated mechanism is also part of the side shaft 29 with retaining arms.

[0024] The starting point of the disposal robot 36 is the vehicle 30 with turntable - conveyance vehicle of the disposal robot which is an analogy of the conveyance vehicle 6. It is also a driven vehicle, it has an extended vehicle frame 31 but the retractable tailstock sleeves 15 are the same. With retractable parts of electronically synchronized retractable tailstock sleeves 15, there is firmly con-

nected the extended superstructure frame 32, in which axis is the turntable 33 with drive which is connected through a flange with the rotatable superstructure 34 on which rear part there is a rope winch 35 with transmission roller stored in the extension.

[0025] Disposal robot 36 is formed by a basic part which is the vaulted frame 37 in which lower longitudinal girders, there are shaped wheels 38 with in-wheel drives arranged in the cones in overhung manner; including a planetary gearbox 39, alternatively.

[0026] An essential mechanical part of the disposal robot 36 is the dual effector 40 which is mounted in the horizontal planar frame 41. This frame is suspended on two pairs of vertical motion screws 42 of the same orientation and the same pitch, firmly constrained in the upper girder of the vaulted frame 37 through gear wheels 43 with nut which are arranged in radiaxial bearings in the planar frame 41; while each pair of the gear wheels 43 with nut is driven by a rotary drive 44 with pinion through a flexible closed element 45, both rotary drives 44 with pinion are part of the planar frame 41, and both rotary drives 44 with pinion are mutually electronically synchronized.

[0027] Dual effector 40 is suspended under the planar frame 41 so that its two longitudinal lateral rows of eyes serve to swivel placement of the effector 46 for manipulation with bentonite fillings and for placement of the effector 47 for manipulation with disposal casks.

[0028] An essential part of the effector 46 for manipulation with bentonite fillings is the round rod 48 with swivel collets 49 of bentonite bed, ended by cylindrical large contact grips 50.

[0029] The effector 47 for manipulation with disposal casks is made so that on the round rod 48, there is arranged in swinging manner the hollow rod 51 with swivel collets 52 of disposal casks ended by shaped large contact grips 53.

[0030] Both lateral parallel pairs of concentric round rods 48 and hollow rods 51 are synchronized by two front-end pairs 54 of toothed segments and driven by linear actuators 55 which are attached always either on the swivel collet 49 of bentonite bed, or on the swivel collet 52 of disposal casks, and on the opposite side in the eye of the planar frame 41. Fitted pins 56 are constrained in the frontal surfaces of the front swivel collets 49 of bentonite bed.

[0031] In the rear part of the vaulted frame 37, there is a frame superstructure 57 in which the winding drum 58 of power and control cable ended by connecting plug 59 is arranged. Further in the rear part of the vault frame 37 being firmly connected to it, there is the safety hook 60 of mechanical connection of the disposal robotic vehicle 32 and the vehicle 30 with turntable - conveyance vehicle of the disposal robot.

[0032] In the entrance part of the construction 9 of disposal borehole, there is built a borehole offset creating a crossing of the disposal robot 36 between the vehicle 30 with turntable and the construction 9 of disposal borehole with a minimal difference in link-up of travelling areas.

[0033] Crossing of the access corridor 7 with the technology corridor is realized by means of the rail turntable 62 which allows the passage of the set 63 of robotic vehicles from one corridor to another.

[0034] All vehicles 30, 6 and sets 63 of robotic vehicles are interconnected via couplings 16 with controlled uncoupling.

Functions

[0035] Robotic system 1 of disposal of disposal casks in the deep geological repository allows deep geological robotic disposal of disposal casks 3 as a part of complex, spatially extensive system of disposal of nuclear waste, including important devices such as railway network 2 with trolley wires, except of the conveyance vehicles 6, vehicle 30 with turntable - conveyance vehicle of the disposal robot and disposal robot 36 which are part of the horizontal deep geological repository 5 consisting of entrance access corridor 7 on which the constructions 8 of technological corridors and construction perpendicular to them link up, namely constructions 9 of disposal borehole serving for placement of disposal casks 3.

[0036] Disposal casks 3 are centrally arranged in the construction 9 of disposal borehole and need to be lined with bentonite. For this purpose, there serve the segments of pressed bentonite fillings 4. Most suitable in the aspect of backfilling here, seem to be the circular bentonite fillings 10 separating the heads of disposal casks 3. Under each disposal cask 3, there is a bentonite bed 11, and in its length, there is the space of construction 9 of disposal borehole filled up with the circular bentonite blocks 12.

[0037] Due to possible manipulation with disposal robot 36 in the construction 9 of disposal borehole, there are holes 13 with inner recess incorporated in the circular bentonite fillings 10 and circular bentonite blocks 12.

[0038] Disposal casks 3 and bentonite fillings 4 are moved into the deep geological repository 5 through the wheeled transport via the inclined tunnel and they are translated through robotic manipulators on the respective driven conveyance vehicle 6, intended for transport of bentonite fillings 4 and disposal casks 3.

[0039] Conveyance vehicle 6 is equipped with incorporated retractable tailstock sleeves 15 in its frame, and in its front-end heads, there are couplings 16 with controlled uncoupling within the storage pockets limiting the swing attached through vertical pins. On the retractable tailstock sleeves 15, there is arranged the superstructure frame 17 firmly connected with them, in which the storage casings 18 are firmly placed, and on the superstructure frame there is firmly interconnected with it the concave superstructure 19 with openings above the storage casings 18 with locking; while the inner diameter of the camber is the same as the diameter of the construction 9 of disposal borehole. This type of vehicle is used to transfer

all types of bentonite fillings 4.

[0040] To transport the disposal casks 3 in horizontal position and their fixation, there is used the stand 20 with fixation inserted into the superstructure 19 of the conveyance vehicle 6. The stand 20 with fixation is inserted through its pins into the storage casings 18 with locking of the superstructure frame 17. The stand 20 with fixation is formed by the rigid structure 21 lined with supporting parts, securing defined supporting contact of the disposal cask 3. In the structure 21 lined with supporting parts, there is placed the fixation mechanism 22 which essential part is mechanism drive 23 including a rotary engine 24, countershaft distribution gearbox 25 following thereon with two outputs, while each of which is connected to a power transmission 26 output shafts are oppositely oriented and followed by the parallel distributor shafts 27 transmitting torque moment with opposite rotation orientation to four-articulated mechanisms 28 located in the front-end parts of the stand 20 with fixation. Each of the four-articulated mechanisms 28 then controls the pivotal movement of the side shaft 29 with retaining arms serving to fix the disposal cask 3 during its transport and in the opposite case, in the initial position, the whole fixation mechanism 22 is folded into the space of structure 21 lined with supporting parts.

[0041] The vehicle 30 with turntable - conveyance vehicle of the disposal robot serves for storage and as initial position for the disposal robot 36.

[0042] The vehicle 30 with turntable - conveyance vehicle of the disposal robot is also driven and, unlike the conveyance vehicle 6, it has an elongated vehicle frame 31 into which, as in the case of the conveyance vehicle 6, the retractable tailstock sleeves 15 are incorporated, and in the front-end heads there are in the vertical pins arranged the couplings 16 with controlled locking, with limited swing within the storage pockets. On the retractable tailstock sleeves 15, there is arranged and firmly connected with them, the extended superstructure frame 32 in the centre of which the turntable 33 with drive is stored, as with the superstructure frame 17, while the concave superstructure 34 on it laid is firmly connected with the turntable 33 with drive, while diameter of its camber is equal to the diameter of the construction 9 of disposal borehole. The disposal robot 36 standing on the vehicle 30 with turntable - conveyance vehicle of the disposal robot is connected to ii through the connection plug 59 of the output of winding drum 58 of the power and control cable and through the output of rope winch 35 with transmission roller, through connection to the safety hook 60 of the superstructure frame 57 of disposal robot 36 serving for the emergency pulling-out of the disposal robot 36 from the construction 9 of disposal borehole.

[0043] Loaded conveyance vehicles 6 pass through the access corridor 7 an on the last railway turntable 62, there must be created a set 63 of robotic vehicles so that it is fully operational upon arrival in front of the construction 9 of disposal borehole.

[0044] Disposal cask 3 and bentonite fillings 4 loaded on the conveyance vehicles 6 line up on the last railway turntable 62 with the arrangement of the T-shaped rails of the railway network 2 with trolley wires in the construction 8 of technological corridor in this way: the conveyance vehicle 6 with stand 20 with fixation and disposal cask 3 will be in the direction of construction 9 of disposal borehole, whereas behind will be the conveyance vehicle 6 with bentonite bed 11. Now, behind the first two conveyance vehicles 6 through the railway turntable 62 on the opposite side of the transport, there aligns the pre-prepared vehicle 30 with turntable - conveyance vehicle of the disposal robot on which the disposal robot 36 will stand, and now behind it into the set 63 of robotic vehicles, there will be the conveyance vehicle 6 with circular bentonite blocks 12 added gradually from the rail of the access corridor 7, and the conveyance vehicle 6 with circular bentonite fillings 10 will be to the last position. Now the set 63 of robotic vehicles interconnected through the couplings 16 with controlled uncoupling moves, and it stops so that the vehicle 30 with turntable - conveyance vehicle of the disposal robot 36 would be in front of the construction 9 of disposal borehole.

[0045] Now the last phase can be started, which is the loading of the products into the construction 9 of disposal borehole.

[0046] Before that, it should be noted that into a newly constructed construction 9 of disposal borehole into its access cross section it is necessary to build in a borehole offset 61 to adapt the approach area into the construction 9 of disposal borehole from the rotatable superstructure 34; and further it is necessary to line the end of construction 9 of disposal borehole with circular bentonite fillings 10 by a special procedure.

[0047] After this preparatory phase, it is possible to backfill the construction 9 of disposal borehole in cyclically repeatable manner, and there the disposal robot 36 finds its use.

[0048] Its supporting part is the vaulted frame 37 in which lower longitudinal girders, there are shaped wheels 38 with in-wheel drives including a planetary gearbox 39, alternatively, allowing the ride in the construction 9 of disposal borehole and at the same time on the superstructures 19 of conveyance vehicle 6 and the rotatable superstructure 34 of the vehicle 30 with turntable - conveyance vehicle of the disposal robot.

[0049] In the upper grinder which is part of the vaulted frame 37, there are firmly placed two pairs of vertical motion screws 42 and on them, there are mounted the gear wheels 43 with nut which are arranged rollingly in radiaxial bearings in the planar frame 41. Each of the front-end pairs, synchronizing motion screw 42 - gear wheel 43 with nut, is synchronized by a flexible closed element 45 and driven by a rotary drive 44 with pinion which are again part of the planar frame 41; while the planar frame 41 is supporting part of the dual effector 40 consisting of an effector 46 for manipulation with bentonite fillings and an effector 47 for manipulation with disposal casks.

[0050] The effector 46 for manipulation with bentonite fillings includes tow opposite parallel arms each of which consists of a round rod 48, swivel collets 49 of bentonite bed ended by cylindrical large contact grips 50.

[0051] The effector 47 for manipulation with disposal casks again includes two concentric opposing parallel arms arranged in swinging manner into side eyes of the planar frame 41, each of which consists of a hollow rod 51, swivel collet 52 of disposal casks ended by shaped large contact grips 53.

[0052] Arms of each of the effectors 46, 47 are controlled by the linear actuators 55 arranged in swinging manner in the vaulted frame 37, synchronization of each of the effectors 46, 47 is provide always by a pair 54 of toothed segments each of which is always located on the front-end heads of the disposal robot 36.

[0053] Part of two front swivel collets 49 of bentonite bed are the fitted pins 56 for gripping and loading of all bentonite fillings 4, except for the bentonite bed 11 for which serve the holes 13 with inner recess which are part of said bentonite fillings 4.

[0054] In the rear part of the vault frame 37 of the disposal robot 36, there firmly connected thereto the frame superstructure 57 into which the winding drum 58 of the power and control cable is inserted with the connection plug 59 serving to supply electrical power and control the disposal robot 36, and further in the lowers part of the frame superstructure 57, there is firmly mounted the safety hook 60 for mechanical interconnection of the disposal robot 36 with the rope winch 35 with transmission roller of the vehicle 30 with turntable - conveyance vehicle of the disposal robot.

[0055] Vertical positioning of the dual effector 40 via the synchronized motion screws 43 enables positioning of all parts of bentonite fillings 4 and disposal cask 3 during their manipulation in front of or in the construction 9 of disposal borehole. Rotary drives 44 with pinion are synchronized electronically.

[0056] The disposal robot 36 moves on the superstructures 19 of the conveyance vehicles 6 and rotatable superstructure of the vehicle 30 with turntable - conveyance vehicle of the disposal robot which have the same diameter as the construction 9 of disposal borehole, as well as disposal robot 36 moves in the construction 9 of disposal borehole.

Disposal of disposal casks 3 occurs as follows:

[0057] First, the circular bentonite fillings 10 are transported individually into the ending part of the construction 9 of empty disposal borehole. This is how the construction 9 of disposal borehole of deep geological repository 5 is prepared, and further it is possible to continue in disposal of disposal casks 3 cyclically. The rotatable superstructure 34 of the vehicle 30 with turntable - conveyance vehicle of the disposal robot turns by 90° and there occurs the vertical and horizontal alignment with rotatable superstructure 34 and the borehole offset 61; the rotatable superstructure 34 returns to its original position; superstructures 19 of other vehicles of the set adjust their height vertically to the same level as the rotatable superstructure 34; and the cycle of disposal can be started.

The course of one disposal cycle:

[0058] Disposal robot 36 picks up through the effector 46 for manipulation with bentonite fillings a bentonite bed 11 from the second conveyance vehicle 6, returns to the rotatable superstructure 34 and after rotation by 90° rides to the end of construction 9 of disposal borehole and lays the bentonite bed 11 at full to the last circular bentonite filling 10. The disposal robot 36 returns, uses the rotatable superstructure 34, picks up a disposal cask 3 via gripping of the effector 47 for manipulation with disposal casks from the first conveyance vehicle 6, and again it rides in the same way to the construction 9 of disposal borehole, and lays the disposal cask 3 on the bentonite bed 11 at full to the last circular bentonite filling 10. Further, this small disposal cycle takes place similarly with that, that the disposal robot 36 start to pick up circular bentonite blocks 12 which are on the opposite side of the vehicle 30 with turntable - conveyance vehicle of the disposal robot with that, that the surrounding volume of disposal cask 3 is being backfilled gradually, always by one piece of bentonite filling 4, and it is finished by circular bentonite fillings 10 prepared on the last conveyance vehicle 6.

[0059] After unloading, the conveyance vehicles 6, except of the vehicle 30 with turntable - conveyance vehicle of the disposal robot and the disposal robot 36, return by railway network 2 with trolley wires to the initial station; and the vehicle 30 with turntable - conveyance vehicle of the disposal robot, with loaded disposal robot 36, remains in the waiting position at the nearest rail turntable 62 of the construction 9 of disposal borehole to complement the central position of a set of 63 robotic vehicles after arrival of loaded conveyance vehicles 6.

INDUSTRIAL APPLICABILITY

[0060] The proposed solution of robotic system assembly for disposal of disposal casks in deep geological repository including a set of constructions of underground system of corridors and boreholes with a rail transport network with trolley wires and a disposal robot of robotic system for disposal of disposal casks in deep geological repository as its main part is intended for the realization of the process of transport, manipulation, disposal and backfilling of disposal casks with spent nuclear fuel into the underground horizontal or subhorizontal disposal boreholes of deep geological repository

List of the Positions Used

[0061]

1. robotic system for disposal of disposal casks in a deep geological repository
2. railway network with trolley wires
3. disposal cask
4. bentonite filling
5. deep geological repository
6. conveyance vehicle
7. access corridor
8. construction of the technological corridor
9. construction of the disposal borehole
10. circular bentonite filling
11. bentonite bed
12. circular bentonite block
13. hole with inner recess
14. vehicle frame
15. retractable tailstock sleeve
16. couplings with controlled uncoupling
17. superstructure frame
18. storage casing with locking
19. superstructure
20. stand with fixation
21. structure lined with supporting parts
22. fixation mechanism
23. mechanism drive
24. rotary motor
25. countershaft distribution gearbox
26. power gearbox
27. distribution shaft
28. four-articulated mechanism
29. side shaft with retaining arms
30. vehicle with turntable - conveyance vehicle of the disposal robot
31. extended vehicle frame
32. extended superstructure frame
33. turntable with drive
34. rotatable superstructure
35. rope winch with transmission roller
36. disposal robot
37. vaulted frame
38. shaped wheels with in-wheel drives
39. planetary gearbox
40. dual effector
41. planar frame
42. motion screw
43. gear wheel with nut
44. rotary drive with pinion
45. flexible closed element
46. effector for bentonite fillings handling
47. effector for disposal cask handling
48. round rod
49. swivel collet of bentonite bed
50. cylindrical large contact grip
51. hollow rod
52. swivel collet of disposal casks
53. shaped large contact grip
54. pair of toothed segments
55. linear actuator
56. fitted pin
57. frame superstructure
58. winding drum of the power and control cable
59. connecting plug
60. safety hook
61. borehole offset
62. rail turntable
63. set of robotic vehicles

Claims

1. The disposal robot (36) for storage of disposal casks in a deep geological repository as part of the robotic system assembly, **characterized in that**
it is formed of the basic part, which is the vault frame (37) in which lower longitudinal girders, there are arranged in cones the shaped wheels (38) with in-wheel drives, arranged in the cones in overhung manner;
where in the inner space of the vault frame (37), there is the dual effector (40) which is mounted in the horizontal planar frame (41) suspended on two pairs of vertical motions screws (42) of the same orientation and the same pitch, firmly constrained in the upper girder of the vaulted frame (37) through gear wheels (43) with nut which are arranged in radiaxial bearings in the planar frame (41); while each pair of the gear wheels (43) with nut is driven by the rotary drive (44) with pinion through a flexible closed element (45); while the rotary drives (44) with pinion are part of the planar frame (41), and the rotary drives (44) with pinion are mutually electronically synchronized;
while the dual effector (40) is suspended under the planar frame (41), while it is further provided with two longitudinal lateral rows of eyes of swivel placement of the effector (46) for manipulation with bentonite fillings and eyes of placement of the effector (47) for manipulation with disposal casks;
where the effector (46) for manipulation with bentonite fillings is forms by the round rod (48) with swivel collets (49) of bentonite bed, ended by cylindrical large contact grips (50), and the effector (47) for manipulation with disposal casks is made such that on the circular rod (48), there is pivotally mounted the hollow rod (51) with swivel collets (52) of disposal casks ended by shaped large contact grips (53);
while both lateral parallel pairs of concentric round rods (48) and hollow rods (51) are synchronized by two front-end pairs (54) of toothed segments and driven by linear actuators (55) attached always either on the swivel collet (49) of bentonite bed, or on the swivel collet 52 of disposal casks, and on the opposite side in the eye of the planar frame (41);
while the fitted pins (56) are constrained in the frontal areas of the front swivel collets (49) of bentonite bed;
while in the rear part of the vaulted frame (37), there is a frame superstructure (57) in which a winding drum (58) of the power and control cable ended by

connecting plug (59) is arranged;
while in the rear part of the vault frame (37) being firmly connected to it, there is the safety hook (60) of mechanical connection of the disposal robotic vehicle (32) and the vehicle (30) with turntable - conveyance vehicle of the disposal robot.

2. The disposal robot (36) as described in claim 1, **characterized in that** the shaped wheels (38) with in-wheel drives include a planetary gearbox (39).

3. The robotic system assembly for disposal of disposal casks in a deep geological repository made up of a system of construction of horizontal corridors system at the entrance of which, there is the access corridor (7) on which the constructions (8) of technological corridor link up transversely, which are linked up perpendicularly at a certain height above the floor by the constructions of horizontal corridors of the constructions (9) of disposal boreholes for central storage of disposal casks (3) lined with space-pressed bentonite fillings (4); when the main part of the robotic system assembly is the disposal robot (36) as described in claim 1, **characterized in that**
a part of the robotic system assembly is the railway network (2) with trolley wires equipped with the borehole offset (61) of the disposal robot (36) between the vehicle (30) with turntable - conveyance vehicle of the disposal robot and the entrance part of the construction (9) of disposal borehole with difference in link-up of travelling areas, as well as the railway turntable (62) of passage of the set (63) of robotic vehicles between the construction of the access corridor (7) and the construction (8) of technological corridor;
while the initial station of the disposal robot (36) an environmentally acceptable way of disposal of the disposal casks in a deep geological repository is the vehicle (30) with turntable - conveyance vehicle of the disposal robot which has the extended vehicle frame (31) in which electronically synchronized tailstock sleeves (15) are stored, while the retractable parts of the electronically synchronized tailstock sleeves (15) are firmly connected with an extended superstructure frame (31) of the superstructure vehicle (34) in which axis there is a turntable (33) with drive which is connected through a flange with a rotatable superstructure (34) on which rear part there is a rope winch (35) with transmission roller;
while the robotic system assembly is further equipped with conveyance vehicle (6) for transport of bentonite fillings (4) and disposal casks, which is formed by the vehicle frame (14) into which the electronically synchronized retractable tailstock sleeves (15) are compiled;
while the couplings (16) with controlled uncoupling with limited swing within the storage pocket are attached through vertical pins in front-end heads of this conveyance vehicle (6);
where superstructure frame (17) with storage casings (18) with locking is arranged on the retractable tailstock sleeves (15); where part of each vehicle frame (14) is the concave superstructure (19) firmly connected with it, with openings above the storage casings (18) with locking; while the inner diameter of the concave superstructure (19) corresponds to the diameter of the construction (9) of disposal borehole; while the stand (20) with fixation for transport of disposal cask (3) is stored in the conveyance vehicle (6); while into the spatial structure of the stand (20) with fixation of the structure (21) lined with supporting parts, there is built-in the fixation mechanism (22) consisting of mechanism drive (23), where the mechanism drive (23) comprises the rotary motor (24), then follows the countershaft distribution gearbox (25), followed by two opposite branches each of which include the power gearbox (26) in the outset its output is followed by the distribution shaft (27) to control the larger lever of the four-articulated mechanism (28), while the smaller lever of four-articulated mechanism is also part of the side shaft (29) with retaining arms.

4. The robotic system assembly as described in claim 3, **characterized in that** the constructions (9) of disposal boreholes are circular in cross-section.

5. The robotic system assembly as described in claim 3, **characterized in that** the bentonite fillings (4) are circular bentonite fillings (10), bentonite beds and circular bentonite blocks (12).

6. The robotic system assembly as described in claim 5, **characterized in that** the circular bentonite fillings (10) and circular bentonite blocks (12) have openings with inner offset.

7. The robotic system assembly as described in claim 3, **characterized in that** the vehicles (30 and 6) forms the set (63) of robotic vehicles.

8. The robotic system assembly as described in claim 7, **characterized in that** the set (63) of robotic vehicles is formed by a set of four conveyance vehicles (6), the first of which is equipped with the stand (20) with fixation, and furthermore with the vehicle (30) with turntable - conveyance vehicle of the disposal robot - and disposal robot (36).

9. The robotic system assembly as described in claim 3, **characterized in that** all the vehicles (30 and 6) forming the set (63) of robotic vehicles are connected through the coupling (16) with controlled uncoupling.

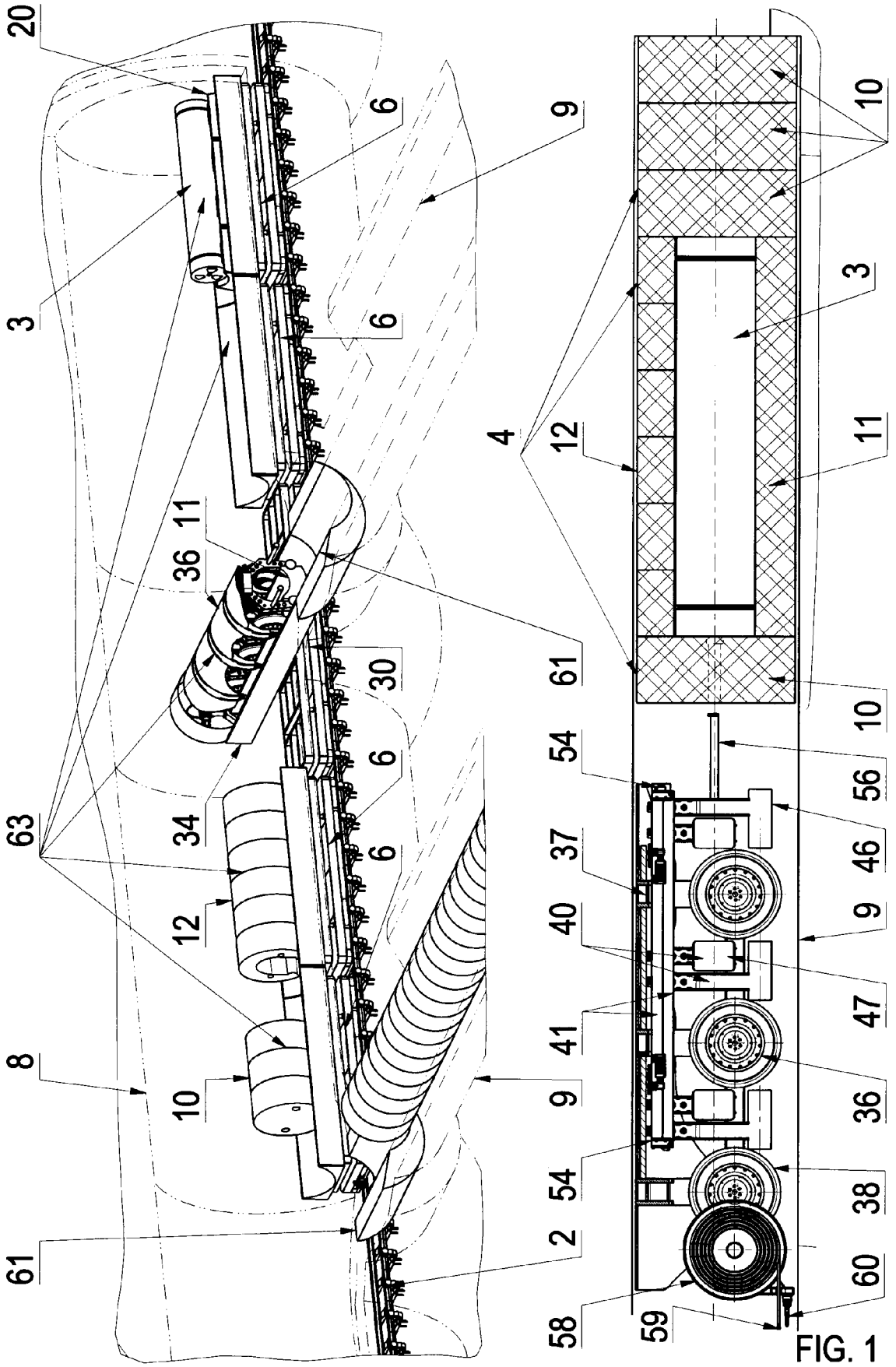
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FIG. 1

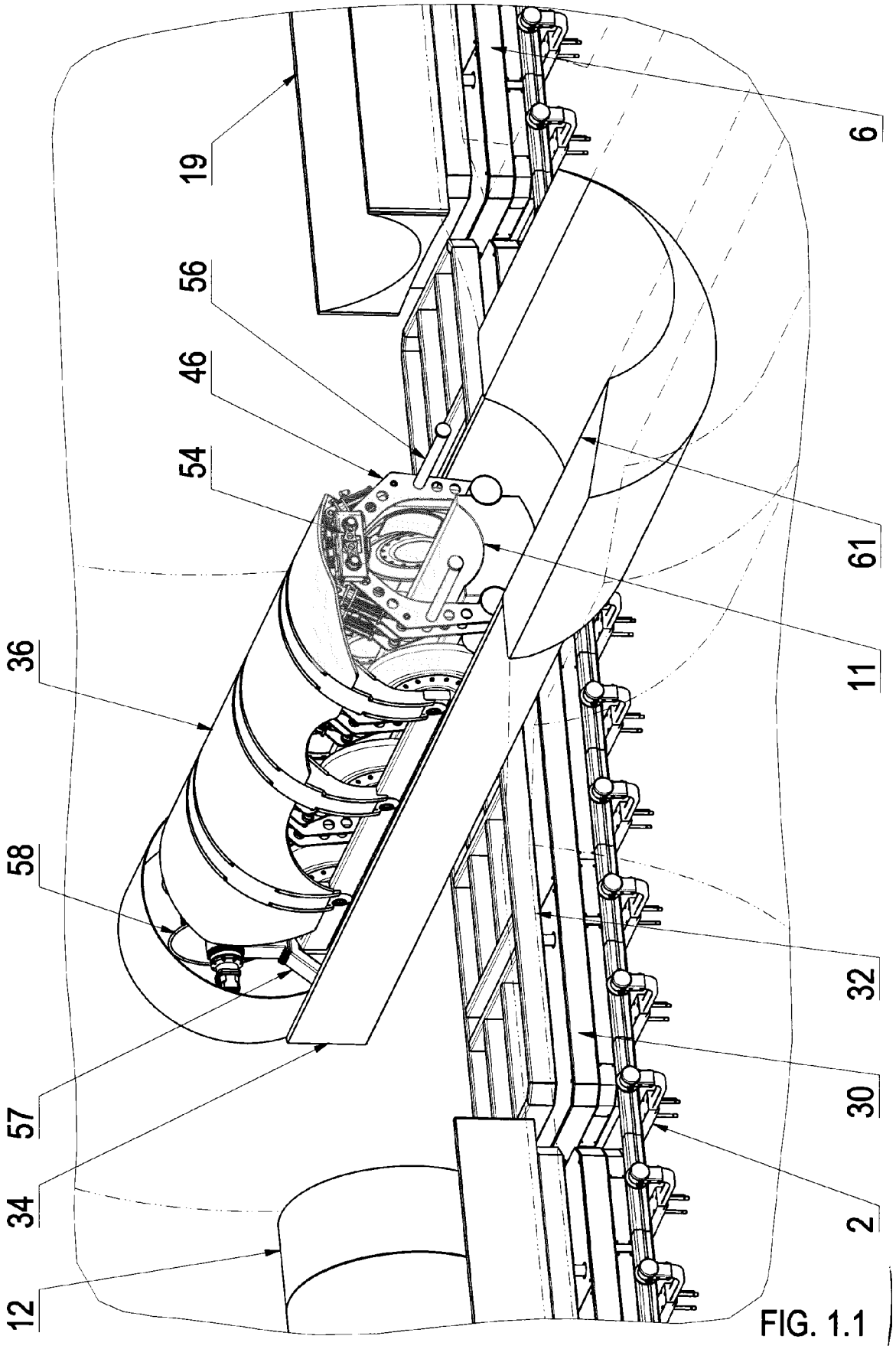

FIG. 1.1

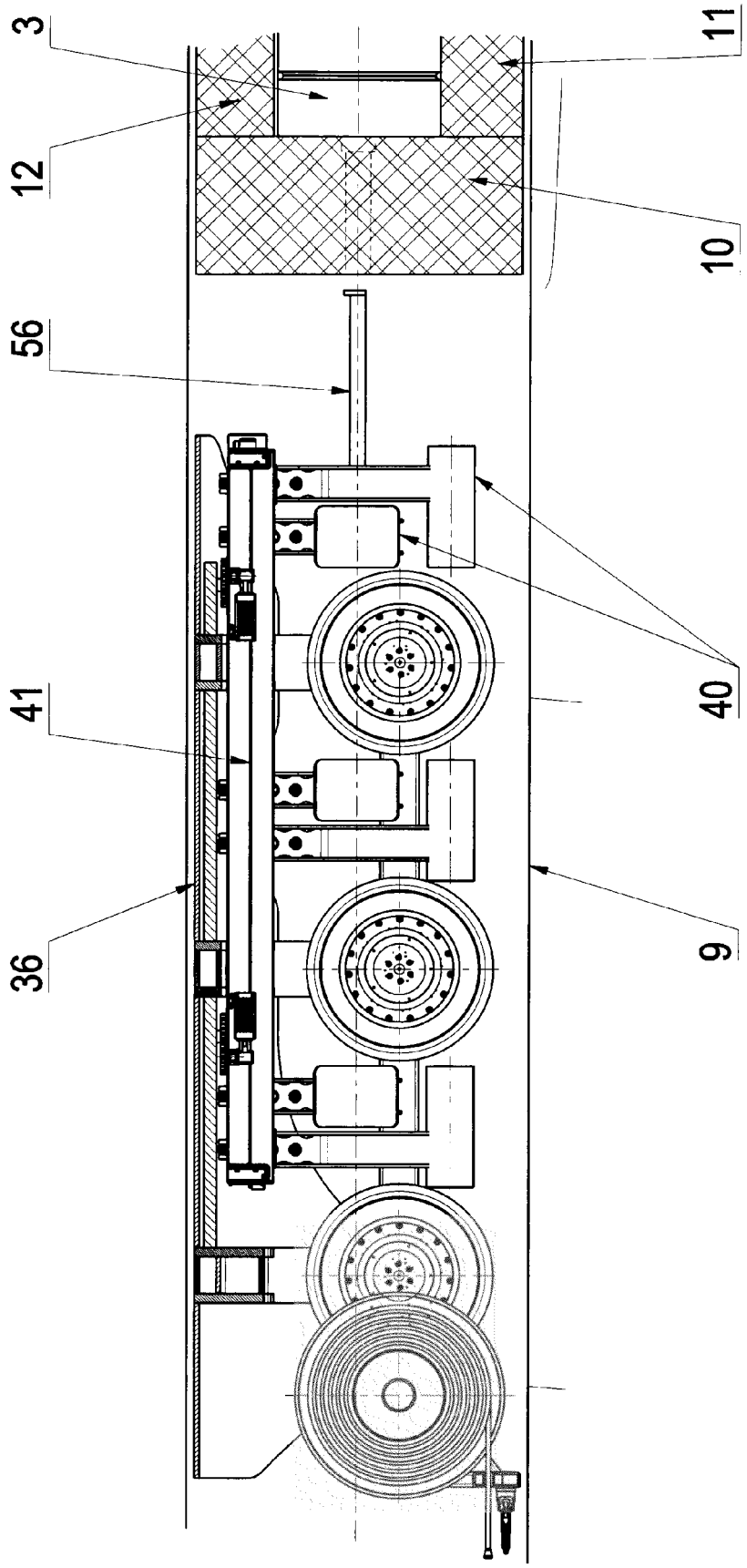

FIG. 1.2

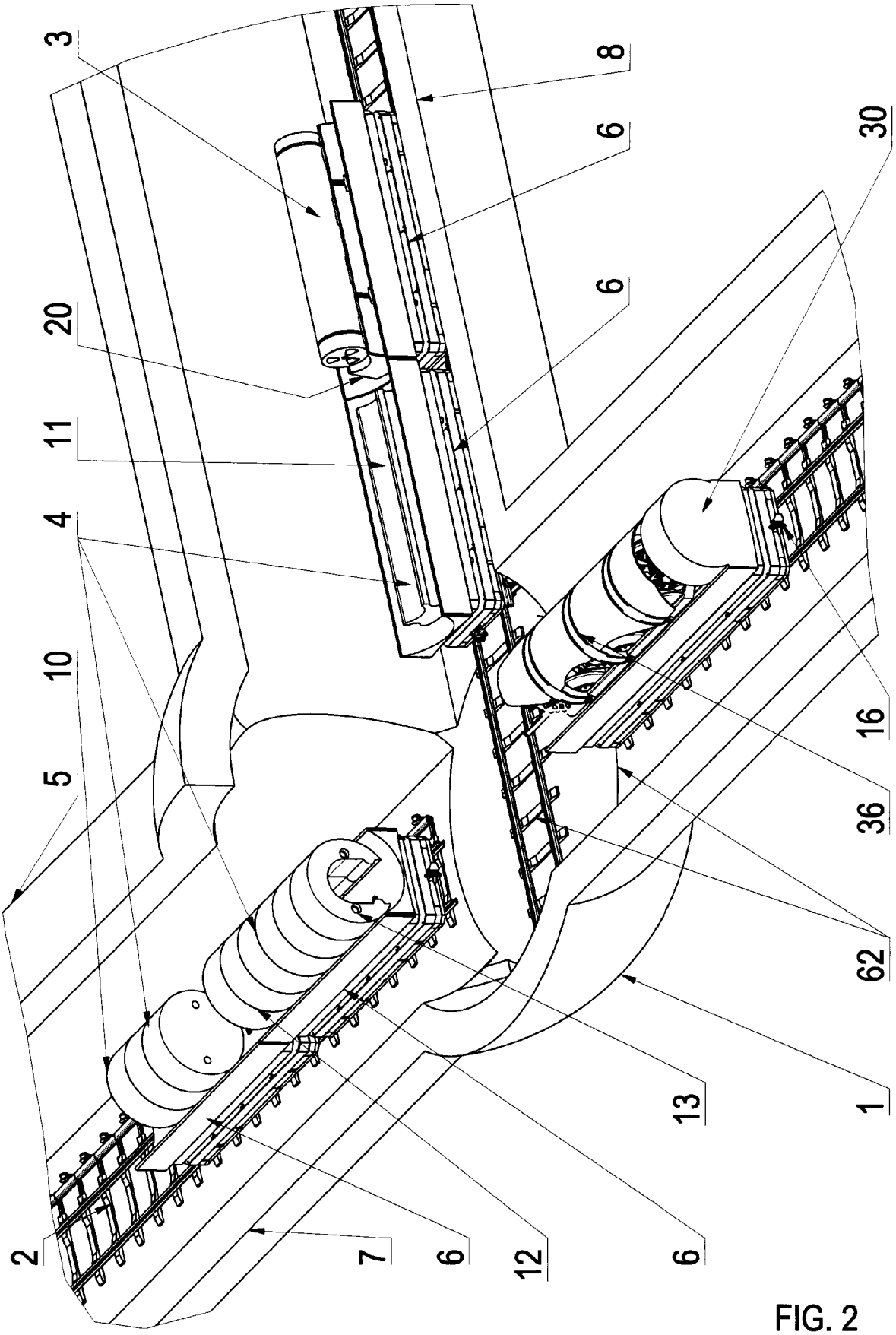

FIG. 2

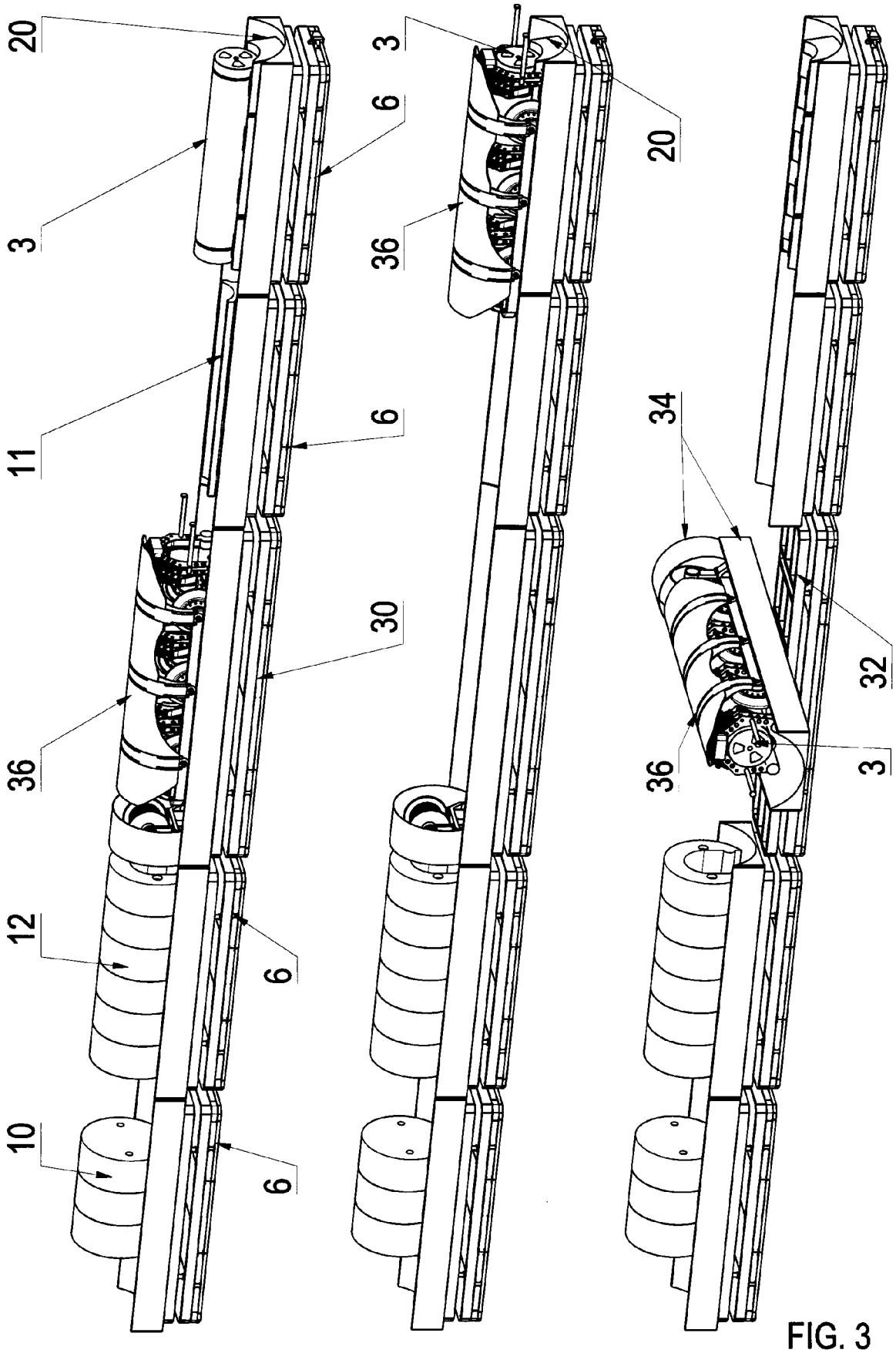

FIG. 3

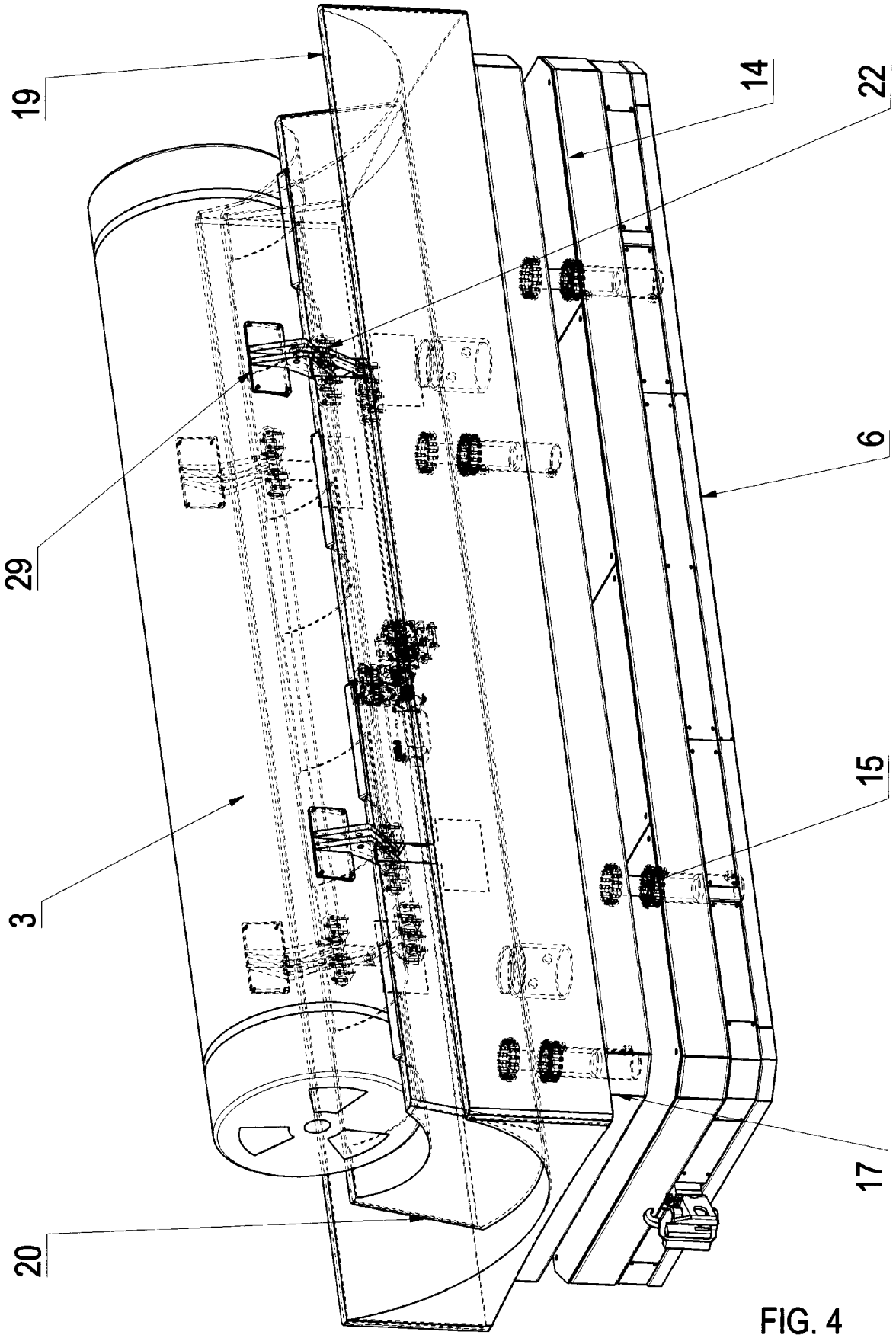

FIG. 4

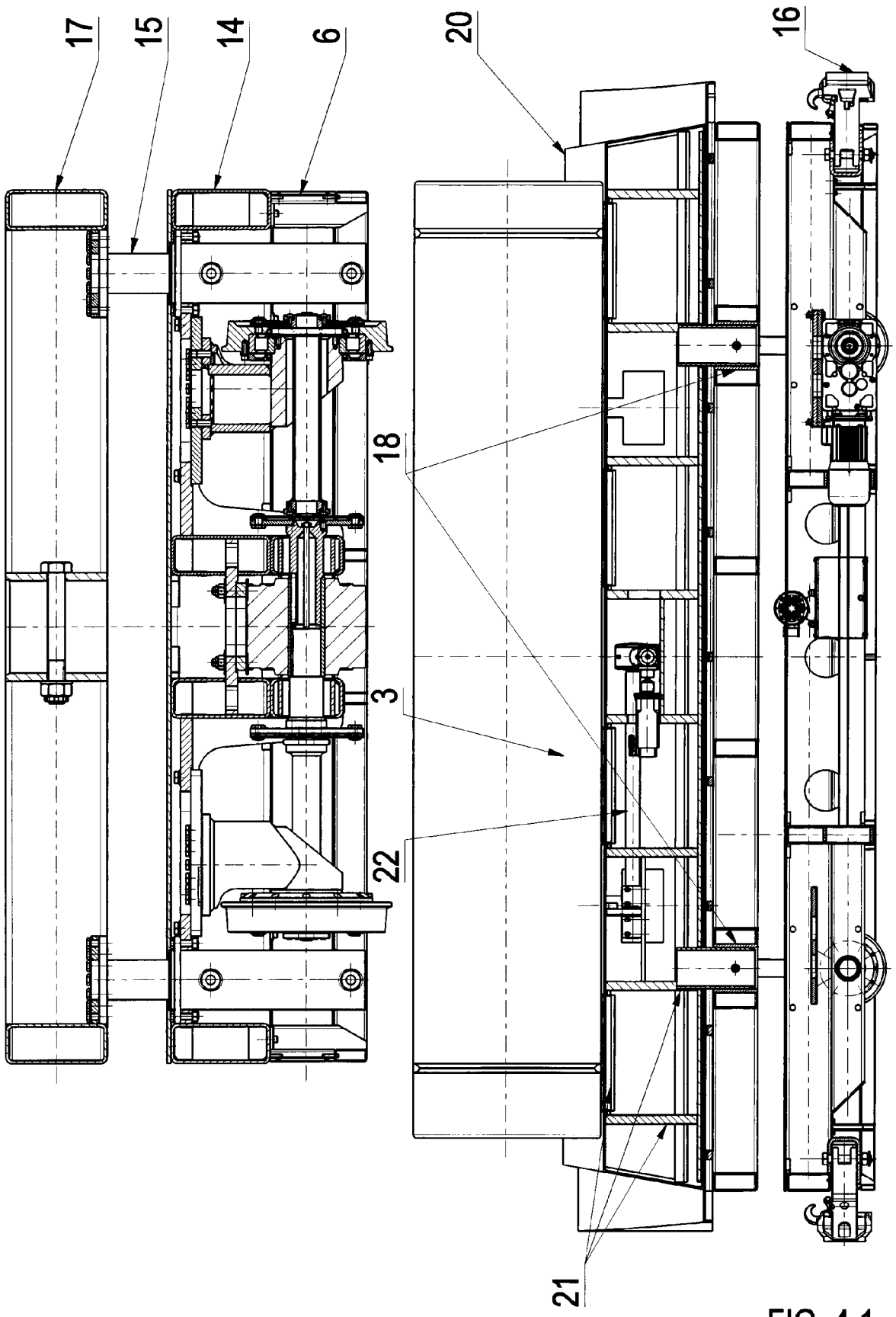

FIG. 4.1

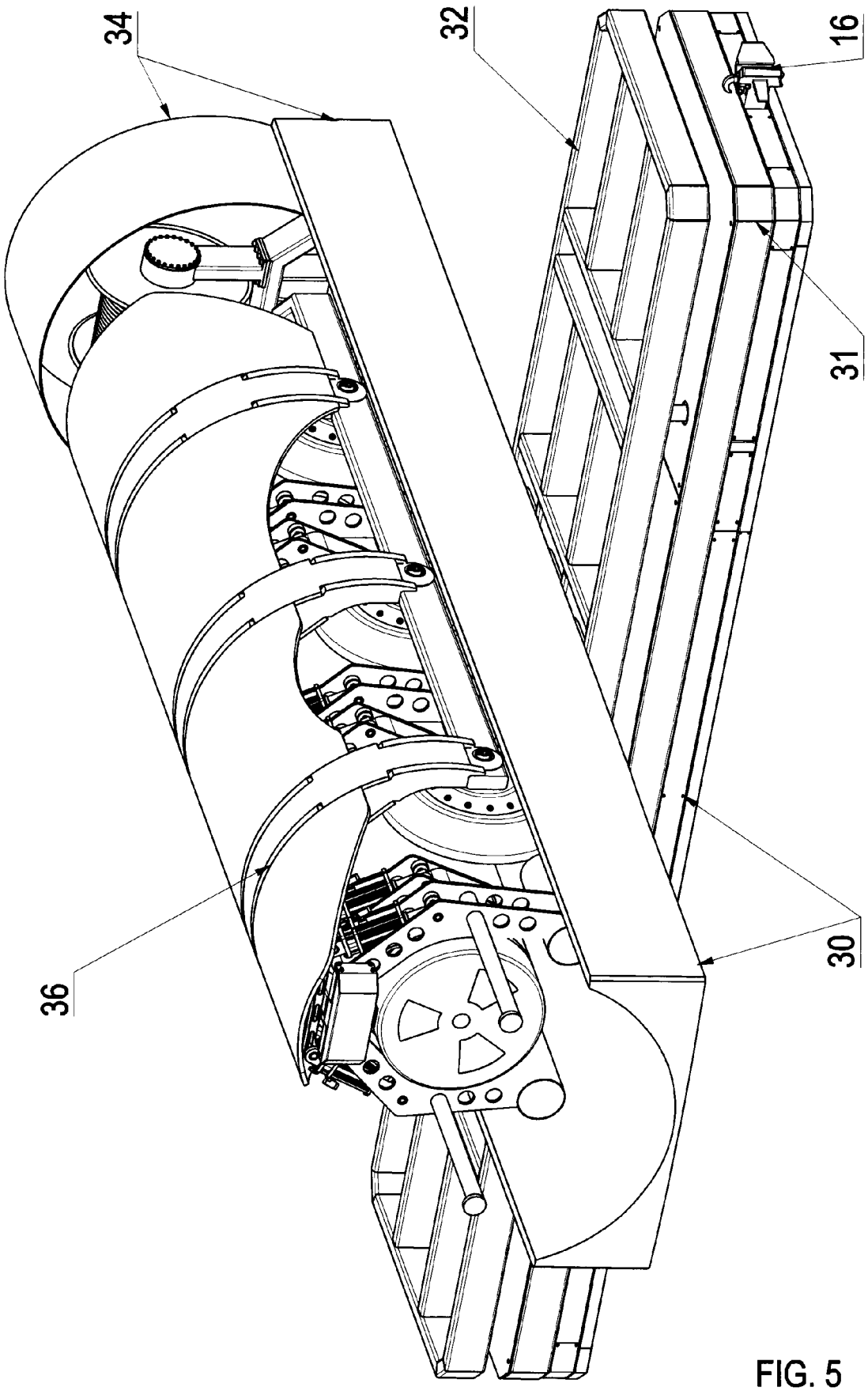

FIG. 5

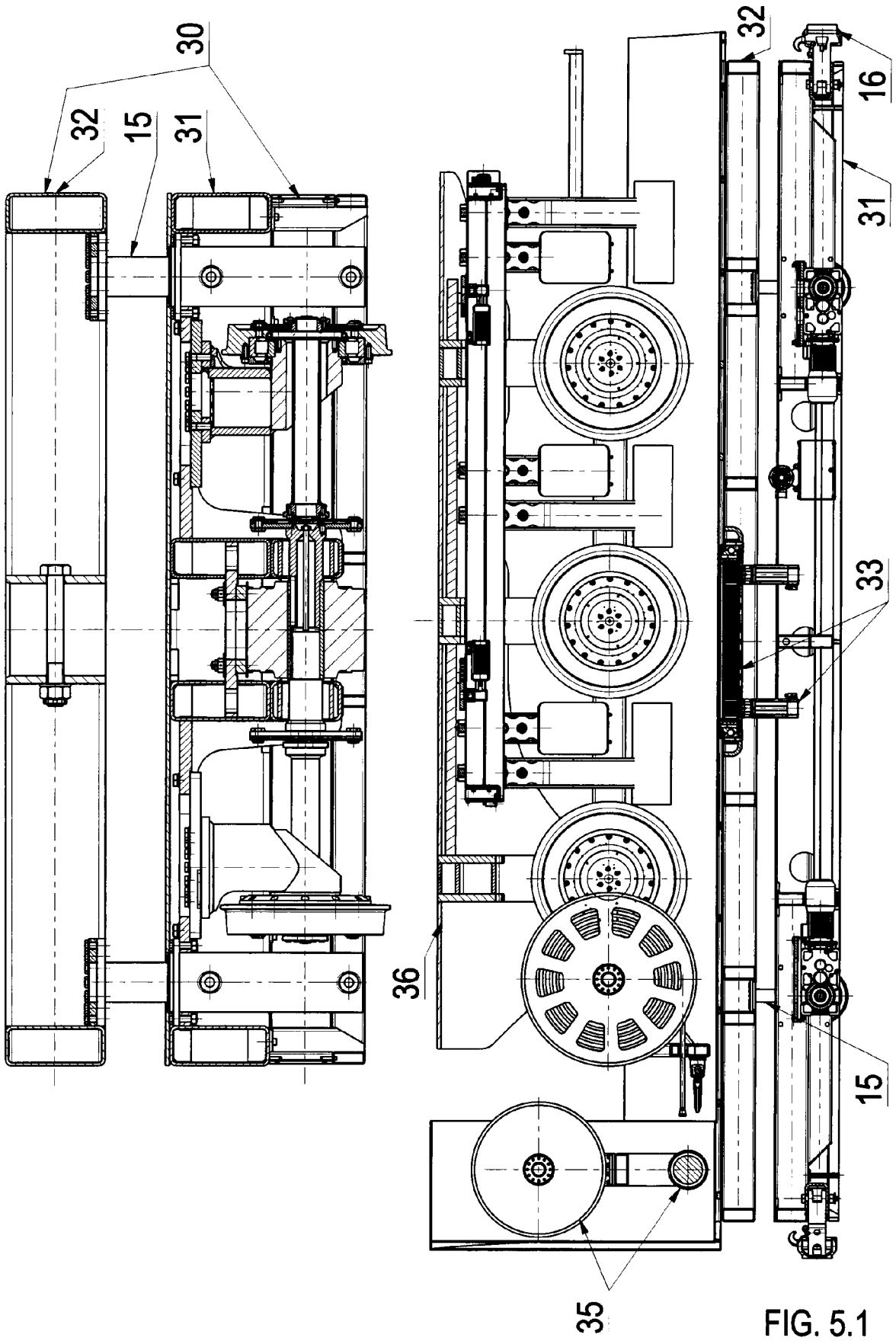

FIG. 5.1

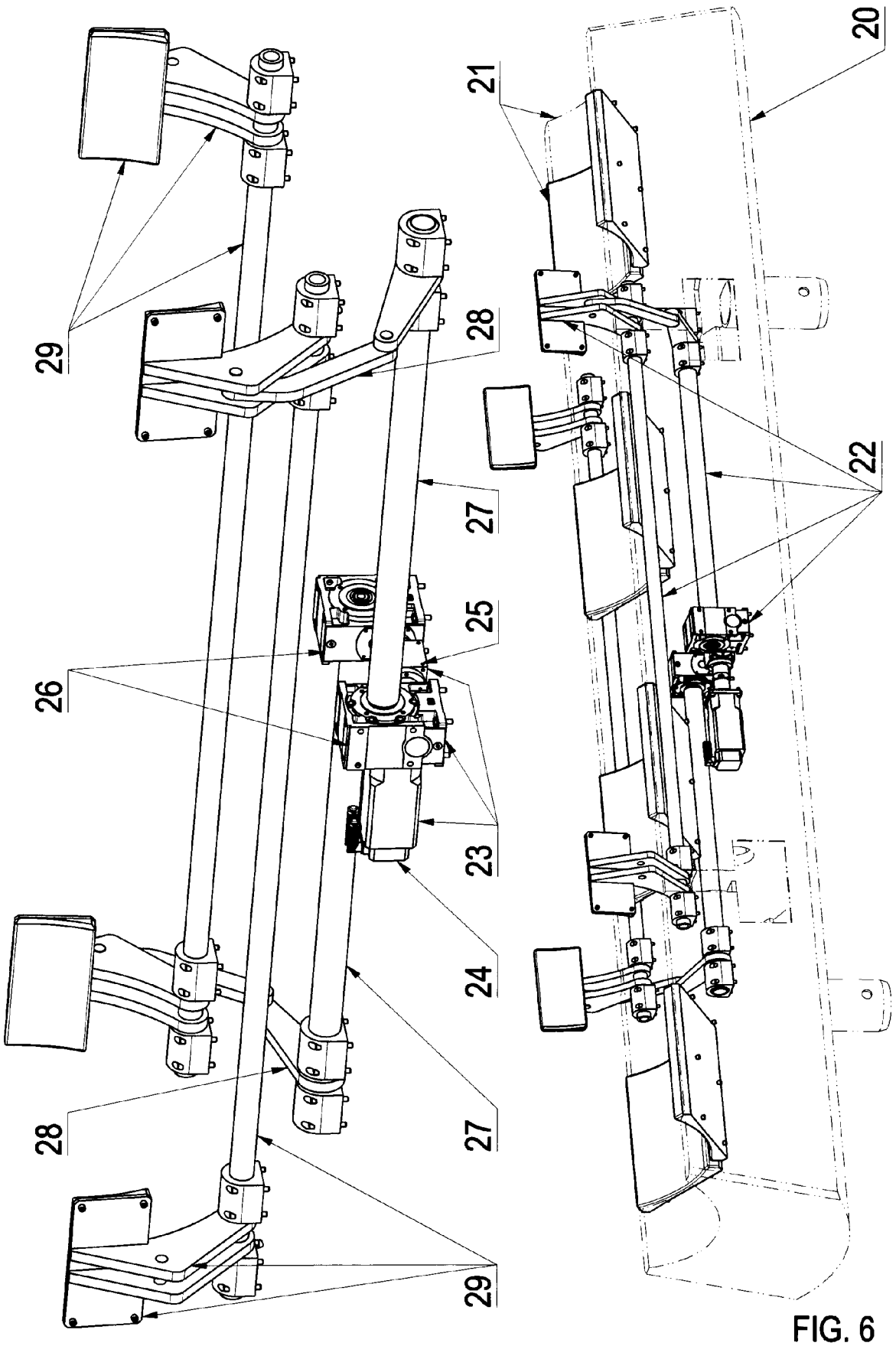

FIG. 6

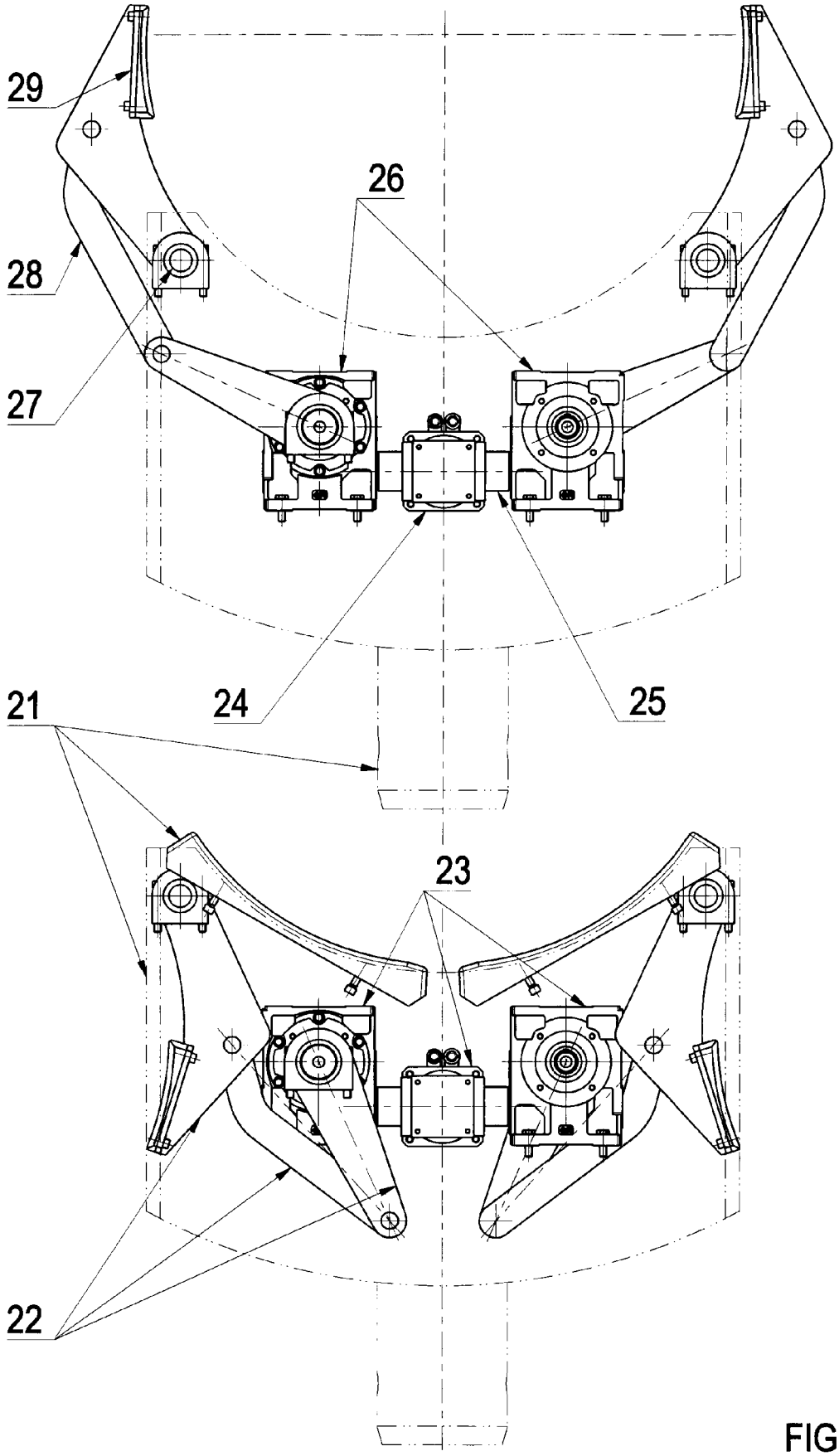

FIG. 6.1

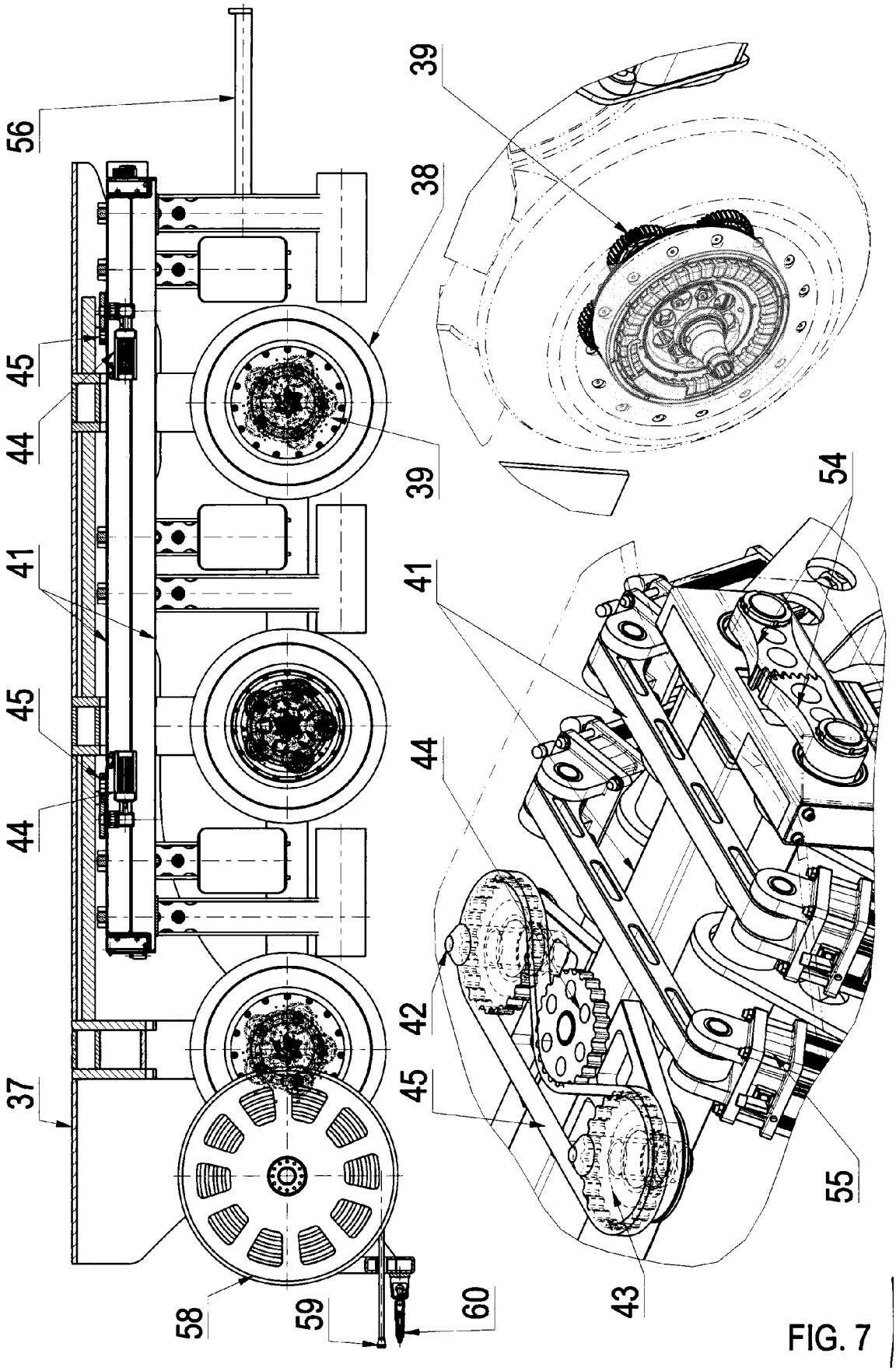

FIG. 7

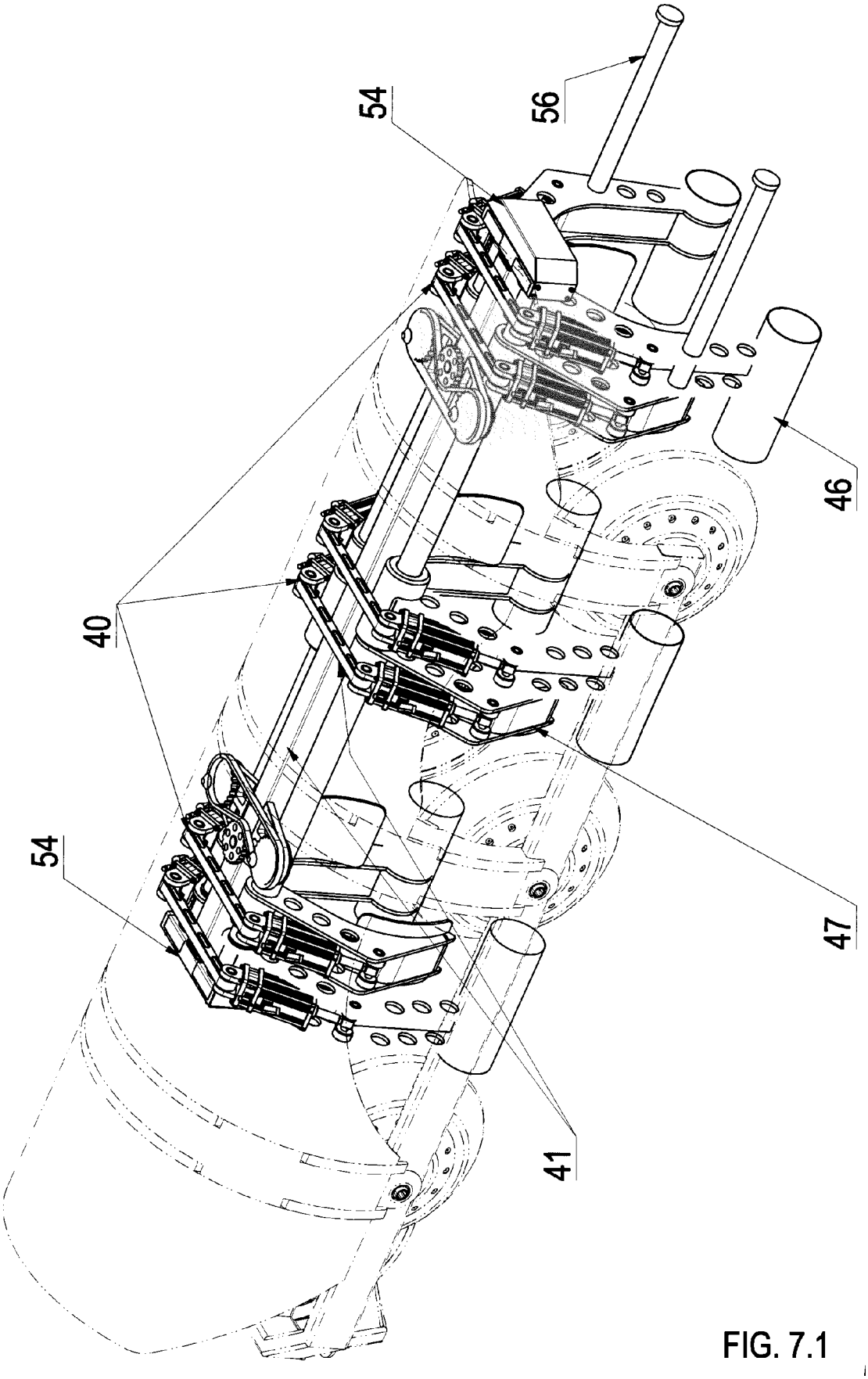

FIG. 7.1

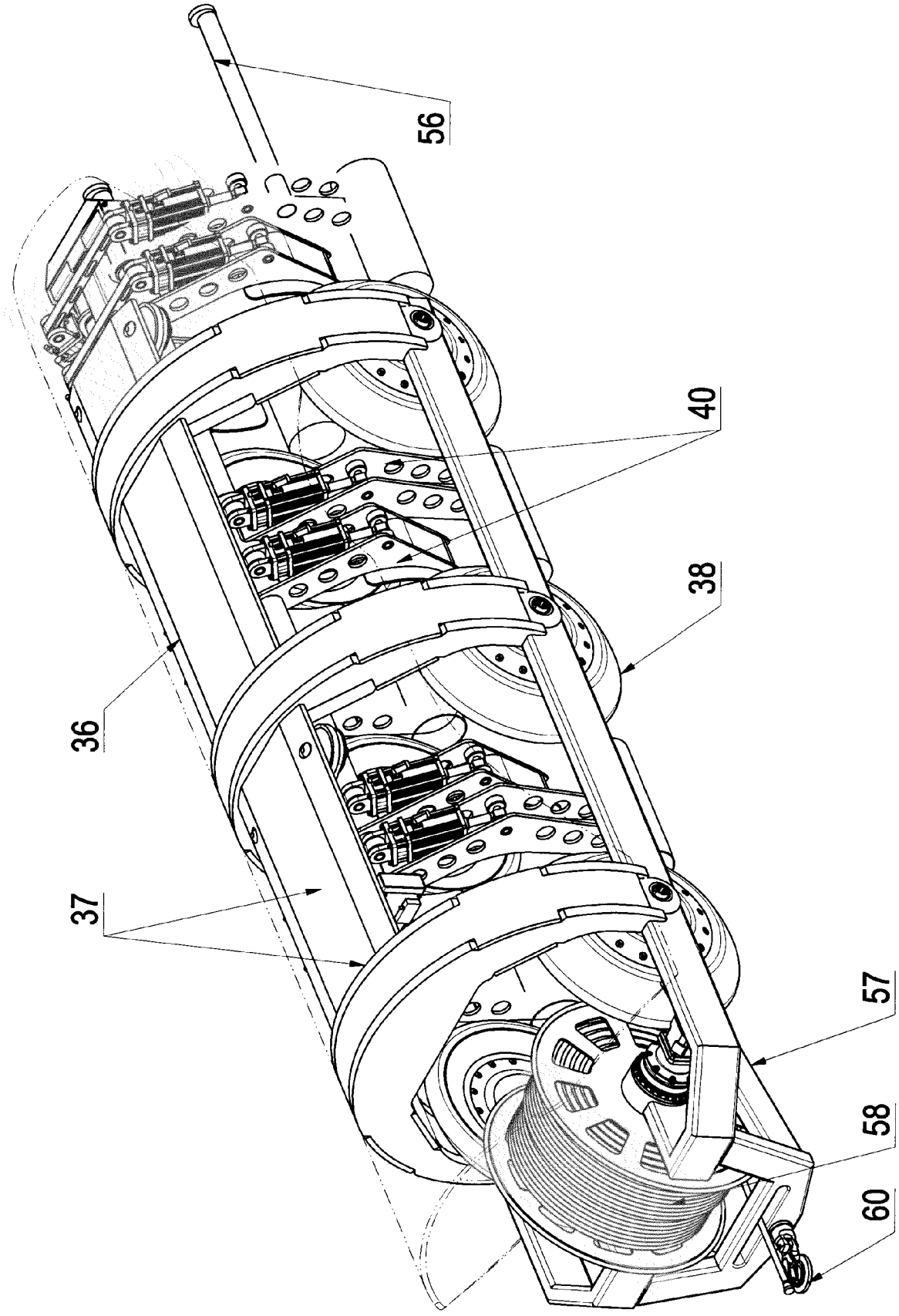

FIG. 7.2

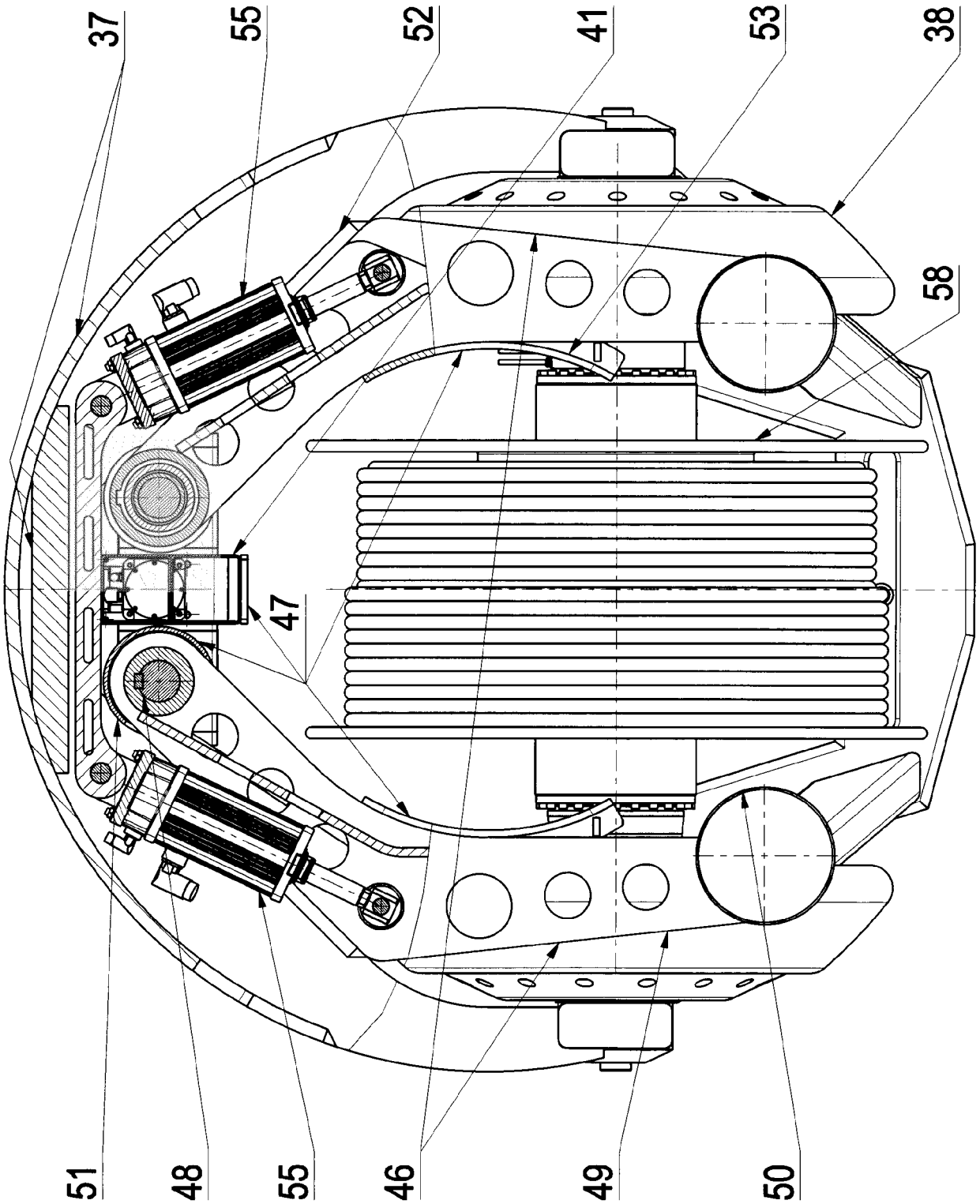

FIG. 8

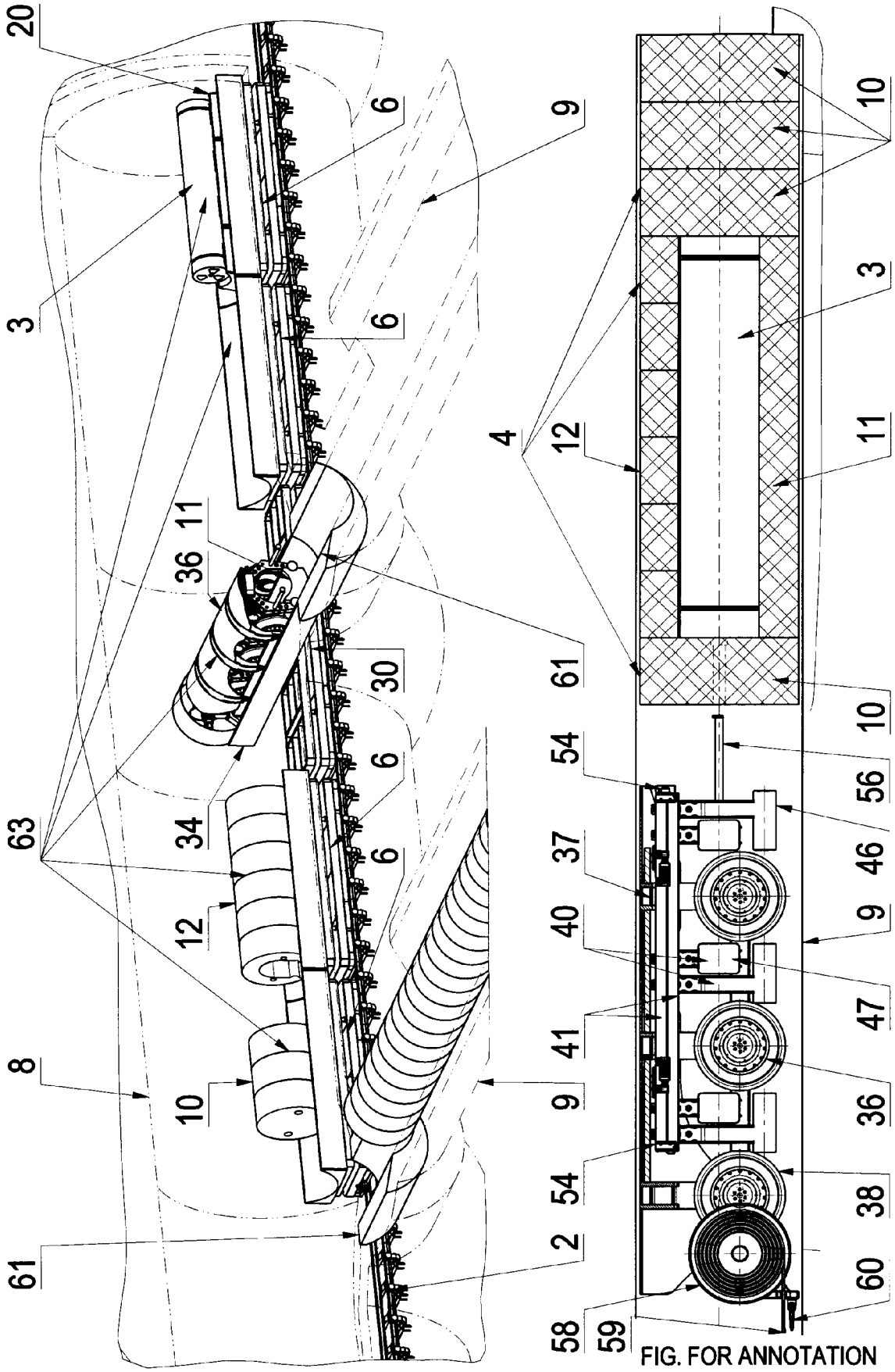

FIG. FOR ANNOTATION

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EUROPEAN SEARCH REPORT

Application Number
EP 18 46 6001

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A,P	EP 3 154 063 A1 (ROBOTSYSTEM S R O [CZ]; HALADOVA PETRA [CZ]) 12 April 2017 (2017-04-12) * paragraphs [0023], [0027] - [0033], [0037], [0038]; figures 1, 3-6 *	1-9	INV. G21F5/14 G21F9/34 B60K7/00
A	US 2011/094815 A1 (TERRY MELVIN DEAN [US]) 28 April 2011 (2011-04-28) * paragraphs [0007], [0052], [0059] - [0067], [0074] - [0075]; figures 1, 2A-2D, 5A-5D *	1-9	
A	"RD&D Programme 2010 TR-10-63", , 1 September 2010 (2010-09-01), pages 1-455, XP055174756, Retrieved from the Internet: URL:http://www.skb.se/upload/publications/pdf/TR-10-63.pdf [retrieved on 2015-03-09] * page 147, line 10 - page 155, line 22 *	1-9	

TECHNICAL FIELDS SEARCHED (IPC)
G21F
B60K

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	19 October 2018	Sewtz, Michael

CATEGORY OF CITED DOCUMENTS

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19-10-2018

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 3154063 A1	12-04-2017	NONE	
US 2011094815 A1	28-04-2011	NONE	

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