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(54) **Title**: AQUACULTURE CAGE SCREEN AND CLEANING APPARATUS

(57) **Abstract**: The device includes a screen cleaning brush with multiple fibers or cleaning fingers made from a flexible material with a hook and barb shape. The hook is designed to trap the screen strand as it passes and rotates on a flexible arm to clean the adjacent and opposite side of the strand and then flexes to release the strand. The instant invention has a unique propulsion system and navigation system that enables automatic navigation of the cleaning apparatus on the screen of the aquaculture cage. Alternative the screen cleaning can be performed with a frame having fins to assist in the directional placement of the cleaning fingers against a submersed screen.

# AQUACULTURE CAGE SCREEN AND CLEANING APPARATUS

## FIELD OF THE INVENTION

This invention is related to the field of open ocean aquaculture and, in particular, to an improved aquaculture cage screen scrubber and cleaning apparatus.

## BACKGROUND OF THE INVENTION

Fish farming or open ocean aquaculture is the rearing of marine organisms under controlled conditions in exposed high energy ocean environments. The purpose of the open ocean aquaculture is to raise a species of fish in a controlled environment wherein the open ocean allows for the natural cleansing of the holding pen. The open ocean aquaculture facilities consist of cages, holding pens, or the like that can be free floating, secured to a structure, or lowered to the ocean bottom. Open ocean aquaculture also makes use of the vast area of the ocean wherein cage size is not limited, as compared to the placement of cages within bays or the like tightly boarded area. The fish farming industry has enjoyed a steady, strong growth for many years and can produce sustainable high quality fish products.

Fish farming has been done for thousands of years, yet in many ways it is still in its infancy. Environmental concerns and labor rates of the developed countries are the new barriers for continued growth of the industry. Offshore aquaculture is among the fastest growing industries today. Fish consumption is rising and wild stocks are unable to meet demand. Many ocean species contain valuable omega 3 oils that are recommended by doctors for good health. These oils are not abundantly found in fresh water species. The health benefits of ocean fish will continue to drive demand for ocean grown fish for decades to come. Offshore

aquaculture has not developed in the United States despite the fact that we have the largest Exclusive Economic Zone in the world at 3.4 million square miles.

Historically ocean water fish farming has been done in protected near shore areas where access to the cages has been very good and cleaning and maintaining cage screens has been affordable and not prohibitive due to open sea conditions, distance and increasing labor rates. The netting is usually coated with antifouling material. The nets are removed and cleaned every few weeks and re-dipped in antifouling material, and then re-entered into the water. This process is presently under attack in Europe and Canada, because of the environmental impacts of the poisons introduced into the water during the cleaning process and while in use. Thousands of fish cages are doing this worldwide. The antifouling that reaches the ocean or bay floor reduces the ability of the floor to deal with by-products from the fish in the very worst cases. Antifouling paints are also under attack by environmentalist and the most effective antifouling paints are already banned in the United States.

Today many countries have used and over used the acceptable protected aquaculture sites and are now forced to go offshore to expand. The U.S. is committed to developing an offshore aquaculture plan for federal waters. Most of the U.S acceptable sites are 10 to 70 miles offshore and in areas that are susceptible to severe weather. The solution for severe weather areas is underwater cages that are not affected by surface waves.

The netting from offshore underwater cages cannot be efficiently removed for cleaning. The current solution is to scrub the cage screen underwater to remove fouling. The use of divers is expensive and the small

fibers of the net contain small amounts of growth after cleaning and re-growth starts immediately.

Holding pens placed in offshore waters employ cages that are lowered and secured to the ocean bottom. Holding pens that are positioned near shore or in bays may consist of floating facilities. Extensive offshore floating facilities are currently found in most coastal countries such as Australia, Chile, China, France, Ireland, Italy, Japan and Norway. The United States has only a few open ocean facilities while other countries are experimenting with such facilities such as Panama, Korea, Spain, Mexico, Brazil and other Central and South American countries. Labor offshore has many difficulties including poor working conditions, health risks and transportation costs. This is especially true for underwater cages where divers are required for almost all of the work.

Environmental risk is the most common reason cited for lack of fish farming in the United States. Another reason is suggested likelihood of disease in densely populated farm cages, the risk of disease increased by unwanted growth on the cage. Unwanted growth also reduces oxygenated water flow through the cage and slows fish growth.

The aquaculture facilities may be used to house many different types of fish such as halibut, haddock, cod, flounder, black sea bass, snapper, cobia, yellow tale snapper, tuna, stripped bass, mahi mahi, and so forth.

An underwater cage is susceptible to vegetation or algae growth which is fairly easy to remove if all sides of the cage material are periodically scrubbed. Fouling on an aquaculture screen is progressive in nature. Frequent cleaning of the earlier stages of

growth help to prevent the growth from reaching later stages of hard growth that becomes progressively difficult to remove. Current cage cleaning methods are simple conventional brush devices used by hand or are power driven. The bending brush bristles can only contact about one-quarter to one-third of the strands at one pass. A second pass in the other direction will affect an additional one-quarter to one-third of the screen stand surface for cleaning. For a complete screening of the opposite side of the screen, the opposite side must also be brushed thereby doubling the cleaning effort.

Also used in the aquaculture industry are high pressure water cleaners. They are 15 to 250 horsepower, with larger units requiring a barge, crane and two operators. This expense is prohibitive for most aquaculture farms and is not suitable for farming offshore where the sea conditions make this type of equipment unusable. Current cage cleaner designs are typically corded and require robust power supplies, typically in the form of a generator on a barge. Aquaculture cages vary from site to site and manufacturer to manufacturer. Most have unique geometries that could pose a problem with corded devices where the cord could tangle with the internal geometry of the cage. Some current and expired technologies have been developed that are smaller electric or hydraulic powered devices. These have not been successful in the industry because conventional brushes do not work well enough and several passes on both sides of the screen are required for complete cleaning.

Additionally, almost all aquaculture cages have structure, such as door frames, fasteners, steep construction surface angles, or corners that prevent the

use of automated cage cleaning devices. Furthermore, many times aquaculture cages have nursery cages tied, usually by rope, inside the aquaculture cages that prohibit automated cage cleaning devices from functioning. Attempts to solve this problem have utilized robotics with tractor drives and live video for remote control. This comes at a very high cost and a human operator is also required.

DESCRIPTION OF THE PRIOR ART

Underwater cleaning devices are generally well known. U.S. Patent No. 4,970,747, to Pastore, discloses a cleaning apparatus for cleaning underwater structures that is comprised of a cylindrical brush having a plurality of bristles that extend radially outward, a sealed electric motor for axially rotating the cylindrical brush, and a winch and cables used to raise and lower the cylindrical brush as it cleans the underwater structure. A substantially rectangular trough is displaced below the cleaning apparatus to collect debris that is removed from the underwater structure as the structure is being cleaned. The bristles are conventionally shaped.

Another type of underwater cleaning system is disclosed in published U.S. Patent Application No. 2002/0073493, to Walton. This system includes a brush or abrasive component which presses and scrubs against the surface to be cleaned, and also includes a fluid jet which drives water away from the surface, thereby producing a force against the surface. The brush is a stationary brush, with a handle for guidance by an underwater diver or from an arm at the surface; or the brush may be rotary or oscillatory to aid with the scrubbing action. The water jet may be incorporated into

a tube which guides the water away from the surface. The tube produces a Venturi or Bernoulli effect which increases the water thrust and thus additional force against the surface.

Another type of underwater cleaning device is disclosed in U.S. Patent No. 3,964,213, to Tobey. This device discloses an abrasive cleaning tool having various shaped ridges (Figure 4); however such ridges are used to assist in the flushing of debris as a carbide treated screen (Figure 3) is used for cleaning.

U.S. Patent No. 3,628,489, to Michaelson, discloses a rotary brush for removing underwater fouling. This brush includes the use of metal blades spaced apart from the brushes to prevent damage to a surface.

U.S. Patent No. 4,084,535, to Rees discloses an apparatus for cleaning or painting submerged surfaces. The apparatus includes rotary brushes that are either pneumatically or hydraulically driven and operated and positioned by underwater divers.

Another underwater cleaning system is disclosed in U.S. Patent No. 6,070,547, to Achord. This device is held to the hull of a ship by suction, which is not possible when used with a cage structure.

U.S. Patent No. 6,886,486, to Van Rompay, discloses the use of elastically deformable material for underwater cleaning of hulls. The material is rubber, or a rubber like material with relief in the form of nubs, ribs or protrusions.

Still another underwater cleaning machine is disclosed in U.S. Patent No. 4,838,193 to van der Tak. This patent discloses an underwater scrubbing machine having rotary brushes for cleaning the growth off of vessels. The scrub brushes are conventional and do not provide any unique function in and of themselves.

U.S. Patent No. 7,748,349, to Thorvardson, discloses a submersible cage having a net cleaning apparatus that consists of apertures in an arm in which fluid and/or a gas can be expelled towards the netting. Brushes are further used in scrubbing and cleaning of the netting. No mention is made of non-conventional bristles on the brushes.

U.S. Patent No. 4,252,081, to Smith, discloses a fish cage that employs buoyancy to rotate the cage and expose portions of the cage above the water line for cleaning.

U.S. Patent No. 5,930,862 is directed to a rug rake having wire bristles that are bent at their distal end.

U.S. Patent No. 4,493,125, to Collins, discloses a toothbrush with curved bristles.

What is lacking in the prior art is an efficient, beneficial and cost effective aquaculture cage cleaning device and system.

## SUMMARY OF THE INVENTION

The present invention includes a screen cleaning brush with multiple fibers or cleaning fingers made from a flexible material with a hook and barb shape. The hook is designed to trap the screen strand as it passes and rotates on a flexible arm to clean the opposite side of the strand and then flexes to release the strand. The cleaning material is ideally made from a rubber type material with good wear and flexible characteristics such as polyurethane, thermoplastic elastomers, silicones and rubbers. The scrubbing elements of the present invention are the breakthrough needed to make more efficient cage cleaning possible.

The current invention includes a scrubbing and cleaning device with a plurality of articulated fingers that can clean both sides of an aquaculture screen with one pass.

Flexible hooked shaped fingers catch the back side of the screen member and are made of soft flexible polymers that will bend and clean as they release. If the fingers are long and stiffer, then the hook will rotate and bring the screen closer to the brush frame making it easier and more effective for the next advancing finger. This capability is a huge advantage where current and lack of support make cleaning significantly more difficult in many cases. Systems with linear motion are also contemplated.

Another problem with fish cage cleaning is wall angles and structure in the cage that interrupt the cleaning path of the scrubber. Such barriers and structure can make automated cleaning very difficult. Reversing one of the several rotating propeller wheels in the present invention can lift the assembly off the cage screen for short periods of time, changing the angle of attack, and then advance forward again to proceed on an alternate route or jump a barrier. The instant invention has unique propulsion and navigation systems that enable the device to jump barriers or corners, such as mechanical bumpers with signal capability. Specific combinations of forward, reverse and stop can drive the scrubber in any direction over any obstacle once the obstacle is located and understood. Likewise specific sensors and software can be used to guide the equipment for any cage environment and configuration. These sensors could include any combination of altitude and positioning sensors, such as electric wave sensors, low frequency communications, GPS, sonar, short baseline

acoustic positioning (SBL), or the like to provide operational efficiency of the device.

Due to the cost-prohibitive nature of cleaning cages by hand, an automated and autonomous cleaner is needed, thereby lowering the cost and making frequent cleaning feasible. The invention includes a self contained power unit. The unit includes lithium polymer batteries that will deliver more than .12 watts per gram and 400 watts per hour. In addition the device can use a brushless D.C. motor that will provide a very high level of performance over a wide range of conditions. The invention maximizes the propulsion and scrubbing finger details and efficiency, thereby radically decreasing the power requirement. The device can achieve rotor tip speeds of 1 to 4 ft./sec. A device with scrubbing fingers of between 40-90 A scale durometer and a double head approximately one meter wide would operate for two hours and weigh less than 100 pounds above the water and be neutrally buoyant. The apparatus will travel at two to four meters per minute and clean 220 to 400 square meters of screen in two hours automatically.

An additional problem with fish cage cleaning is nursery cages tied with several ropes inside the fish cage because the nursery ropes can interrupt the movement of the scrubber. Such interruption can make cleaning difficult and require human interaction. The instant invention additionally comprises a guard bumper that includes a forward bar for diverting the advancing scrubber around the nursery support ropes. The forward bar can be pointed or V-shaped enabling the forward bar to contact the nursery ropes without impeding the advancing scrubber.

Aquaculture cage surfaces are orientated unpredictably underwater due to the loose movement and

pliability of screen and net aquaculture cages. Propeller wheels can suck the screen and net aquaculture cages into wheels resulting in unpredictable engagement of the netting to the wheels and then unpredictable movement and cleaning of the wheels about the aquaculture cage. The closely fit guard bumper improves control of the scrubber because it more accurately controls the relation of the scrubbing wheel and cleaning fingers with respect to the screen and net surface resulting in improved tilt and depth control effectively adjusting forward movement forces and cleaning control. The apparatus includes an interior wheel circumventing bar for additional control and improved cleaning near the center of the wheels. The interior wheel circumventing bar prevents the net from bunching between the cleaning wheels.

The instant invention includes a housing containing, inter alia, the battery and gear motor drive. The housing can include a pressurized volume that demonstrates and identifies a sealed system. The operator identifies that the system is pressurized before submerging the housing to prevent water damage to the system.

The housing may be less dense than the water resulting in a positively buoyant housing. Alternatively, the propeller has a greater density than the water resulting in a negatively buoyant propeller. The combination of the housing and the propeller may result in a negatively buoyant system. Therefore, it is desirable to make a guard bumper from hollow tubing to increase the buoyancy of the system to near neutrally buoyant. The instant invention includes a hollow guard bumper formed from 2.25 inch diameter .065 inch wall aluminum tubing for maintaining near neutral buoyancy.

The surface of at least a portion of scrubbing wheels are recessed relative to the guard bumper for preventing bunching of the net as the scrubbing wheels rotate.

Removably attached to the system includes a member having a density for making the system negatively buoyant for lowering the cleaning apparatus beneath a water surface. The cleaning apparatus includes a member rope or wire secured to the bumper or body of the cleaning apparatus system for lowering and raising the cleaning apparatus. The rope being secured on a first end to the scrubber and on a second end to a winch.

A noticeable feature of the instant invention is that the scrubbing wheel can be mounted off center of the drive axis for a one hundred eighty degree (180°) synchronous offset for scrubbing the clearance zone between the wheels. In addition to scrubbing the clearance zone between the wheels, the scrubbing wheel has shown improved performance and improved mobility to climb across angled surfaces when the wheels are mounted ¾ inches to 1 ½ inches off center.

An additional feature of the instant invention is that each scrubbing wheel can be tilted across its diameter for improved cleaning near center and improved movement across structure, such as door frames, fasteners, and steep construction surface angles or corners. An observed feature of the instant invention includes introducing a system wobble to overcome a 1 ½ inch high 90° door recess, the system wobble is introduced by tilting the scrubbing wheel ¾ inch across the scrubbing wheel diameter.

Aquaculture surface cages commonly implement handrails. The handrails are approximately one meter (1m) above the water line. In yet an additional feature of the instant invention, the cleaning apparatus includes

a tractor drive designed to drivably connect to the hand rail found on the aquaculture surface cages, the tractor drive is preferably battery powered. The tractor drive shall slowly advance along the hand rail or any elongated surface. A winch is provided about the tractor drive, the winch pulling the scrubber for ascending the underwater scrubber, the winch letting out the scrubber for descending underwater scrubber.

As shown in FIGS. 21A and 21B, handrails commonly found on aquaculture surface cages 300 are on the inward side of the dock floating assembly. The handrails 302 being located on the inward side of the cage enclosure causes fouling to be pushed inside the cage by the scrubber.

As shown in FIGS. 22A and 22B, reversing the construction of the cage dock and rail, or constructing an additional rail outside of the dock diverts the fouling away from the cage as the scrubber cleans from the outside of the cage for preventing fouling buildup inside of the cage.

In a favorable embodiment of the instant invention, the propellers are in a stalled or near total slip condition against the cage. Unlike normal propellers designed with increasing angle to the drive shaft for creating constant forward advance as propeller diameter increases, the cage scrubber propellers of the instant invention operate with a constant angle to the propeller shaft of about 45° for approximately 10% more efficiency.

In a stalled condition against the cage substantial propeller swirl is created that contributes to loss of efficiency. Propeller counter rotation increases approximately 10% efficiency though propeller swirl recovery. Jet pumps often use a stationary stator

blade to recover the same energy. The stalled condition energy swirl in the scrubber drive has dramatically higher swirl losses. Including two 2 ½ inch wide stators in the scrubber drive increased efficiency over 20% for allowing for less propeller blade area to achieve a 10 lb forward force. It has been discovered that twelve blade propellers versus eight blade propellers produce similar results.

Accordingly, it is an objective of the instant invention to provide a cleaning device for an aquaculture cage having scrubbing fingers that are highly efficient and effective that will clean both sides of the cage screen with a single pass.

It is a further objective of the instant invention to provide an aquaculture cage cleaning device that maximizes the efficiency of the propulsion system of the apparatus thereby radically decreasing the power requirement.

It is yet another objective of the instant invention to provide an aquaculture cage cleaning device that can be automatically navigated over the surface of a cage regardless of the environment or cage configuration.

It is a still further objective of the invention to provide an aquaculture cage cleaning device that utilizes brushless DC motors that can be powered with either an integral battery system or power cord.

It is yet another objective of the instant invention to provide an aquaculture cage cleaning device that is driven by a tractor.

It is yet another objective of the instant invention to provide a scrubber that is raised and lowered by hand, by a hand crank system or by a tractor. A tractor may utilize electric, air or hydraulic power for lowering and raising the scrubber

Other objects and advantages of this invention will become apparent from the following description taken in conjunction with any accompanying drawings wherein are set forth, by way of illustration and example, certain embodiments of this invention. Any drawings contained herein constitute a part of this specification and include exemplary embodiments of the present invention and illustrate various objects and features thereof.

## BRIEF DESCRIPTION OF THE FIGURES

Fig. 1 is a perspective view of the aquaculture cage and the cleaning apparatus with the screen material removed for clarity;

Fig. 2 is an enlarged perspective view of the cleaning apparatus within area A as shown in Figure 1;

Fig. 3 is an enlarged view of the screen material as attached to the superstructure of the aquaculture cage;

Fig. 4 is a perspective view of a three headed cleaning apparatus;

Fig. 5 is a perspective view of a single head cleaning apparatus;

Fig. 6 is a perspective view of a cleaning brush rotor;

Fig. 7 is a perspective view of the hub without fingers, propeller blades and mounting ring for the brush material;

Fig. 8 is a side view of the brush fingers prior to installation;

Fig. 9 is an enlarged view of one of the brush fingers as shown in circle B in Figure 8;

Figs. 10A through 10D show the interaction of the deformable brush finger with a screen strand as it

approaches the strand, engages the strand and releases the strand;

Fig. 10A is a view of a strand engaging an end of the finger;

Fig. 10B is a view of a strand entering the U-shaped pocket of the finger;

Fig. 10C is a view of a strand causing extension of the finger;

Fig. 10D is a view of a strand about to leave the end of the finger;

Fig. 11A is a perspective view of a cleaning brush structure with wings;

Fig. 11B is an enlarged view of the cleaning brush fingers used on the cleaning brush structure;

Fig. 12 is a view of the cleaning apparatus engaging a cage;

Fig. 13 is a side view of a scrubber having a propeller and cleaning fingers;

Fig. 14 is a perspective view of a scrubber wheel mounted off center of the drive axis;

Fig. 15 is a side view of a scrubber wheel titled across the wheel diameter;

Fig. 16 is a side view of scrubber wheels tilted outwards from center across the wheel diameters;

Fig. 17A is a perspective view of the tractor mounted to the handrail;

Fig. 17B is an enlarged perspective view showing a portion of Fig. 17A;

Fig. 18 is a top view showing a particular design of the cleaning apparatus having a gimbal support with two degrees of freedom;

Fig. 19 is a top view showing a particular design of the cleaning apparatus having a gimbal support

with two degrees of freedom about a pitch axis P and a yaw axis Y;

Fig. 20A is a perspective view showing a particular design of the cleaning apparatus having a gimbal support with two degrees of freedom about a pitch axis P and a yaw axis Y;

Fig. 20B is an enlarged perspective view showing a portion of Fig. 20A including a gimbal limiting arm that interacts with a middle beam slot;

Fig. 21A is a view of an aquaculture cage having a handrail surface on the inward side of the dock floating assembly;

Fig. 21B is an enlarged perspective view showing a portion of Fig. 21A;

Fig. 22A is a view of an aquaculture cage having a handrail surface on the outward side of the dock floating assembly;

Fig. 22B is an enlarged perspective view showing a portion of Fig. 22A;

Fig. 23A is a view of an aquaculture cage having a handrail surface on the outward side of the dock floating assembly; and

Fig. 23B is an enlarged perspective view showing a portion of Fig. 23A.

## DETAILED DESCRIPTION OF THE INVENTION

Aquaculture cages will experience two types of growth, which for reference will be called soft and hard. Soft growth is bacteria, fungus, algae, diatoms and grass. Hard growths are barnacles, oysters, mussels, clams, etc. Hard growths can be inhibited with a combination of surface finish and flexibility that affect their ability to attach to the cage. Controlling hard growth with screen extruded or molded plastics can be

accomplished by keeping the flex modulus low enough to allow some flexing during use. The hard growths attachment gets stressed because the shell will not flex as screen flexing occurs and they cannot maintain attachment and fall off the screen. Flex modulus of plastics of 500 ksi and lower in diameters of 3.5 mm and smaller have been found effective to release hard growths of barnacles, clams, oysters and tube worms. Tensile strength of 8,000 psi have been found suitable with a surface durometer of D 75 or higher have been found effective against predators.

Soft growths can be more difficult to control, however tests have shown that they form more slowly on smooth hard surfaces and on surfaces with lower co-efficient of friction like PTFE and other low co-efficient of friction flouropolymers. Copper and silver are the oldest known antimicrobials and are effective against small soft growths; however weight, cost and fatigue are a problem for metal screens.

Many antimicrobial products for plastics have been developed for the medical industry. They are generally too expensive for other markets. The antimicrobial additive is usually blended into the plastic between one half and two percent at a minimum effective quantity to control cost. Most of the antimicrobial is locked deep inside the part where it cannot be beneficial and only a small surface quantity is effective. However, this process keeps the antimicrobial locked in the polymer and does not allow the antimicrobial to pollute the environment.

The present invention will mechanically clean the strands of material on aquaculture cage screens regardless of the material used for the strands and the types of growth needed to be removed.

Figure 1 illustrates an aquaculture cage 1 having a plurality of support members 2 to form the superstructure for the cage 1. In this illustration the screen material has been removed for clarity. In practice, the entire cage 1 is enclosed by screening material that is attached to the surrounding support members 2. Located within the interior of the aquaculture cage 1 is a cleaning apparatus 4 of the instant invention. The cleaning apparatus 4 is preferably positioned within the cage but could, if desired, be positioned on the outer surface of the screening material.

Figure 2 is an enlarged view of the cleaning apparatus 4 as shown within circle "A" in Figure 1. This view shows a three unit cleaning apparatus 4 but it is contemplated that the number of units could range from one to as many as needed to suit that size and geometry of the cage 1.

Figure 3 is a perspective view of an illustrative screen 6 as it is attached to one of the support members 2. The screen 6 is comprised of strands 7 of material that are orthogonally oriented to one another thereby creating a grid. The openings 8 within the grid are sufficiently small enough to retain the farmed fish within the aquaculture cage 1.

Figure 4 is an illustration of a cleaning apparatus 4 having three units 10A, 10B and 10C. Unit 10A is connected to unit 10B by one structural beam 12 and to 10C by another structural beam 12. Likewise unit 10B is connected to unit 10C by a third structural beam 12. Each of the units 10A, 10B and 10C has a housing 14. Each housing 14 includes a self-contained power unit. The housing 14 includes lithium polymer batteries that will deliver more than .12 watts per gram and 400 watts

per hour. Alternatively, the cleaning apparatus can be powered by a tethered external power source located out of the water. In addition, each housing 14 includes a brushless D.C. motor that will provide a very high level of performance over a wide range of conditions. One or all of the housings 14 contain sensors to facilitate the navigation of the cleaning apparatus within the aquaculture cage. Each unit also includes an external handle 16 that would enable a driver(s) to manually maneuver the cleaning apparatus in the water. The output of the motor contained within each housing 10A, 10B and 10C is connected to a head 20A, 20B and 20C through a rotary output shaft. Alternatively, the power unit can be either pneumatically or hydraulically driven.

Figure 5 shows a single cleaning unit including a housing 14 with a handle 16, a cleaning brush head (20A, 20B, 20C) as well as a navigation sensor 22. Each unit can be fitted with a sensor 22. The sensors can be mechanical bumpers with signal capability. Specific combinations of forward, reverse and stop for each unit independently can drive the cleaning apparatus in any direction over any obstacle once the obstacle is located and understood. Likewise specific sensors and software can be used to guide the equipment for any cage environment and configuration. For example, the cage may be equipped with a home signaling device which is in communication with one or more sensors on the cleaning device. These sensors could include any combination of attitude direction and positioning sensors, such as electric wave sensors, low frequency communication, GPS, sonar, short baseline acoustic positioning (SBL), or the like to provide operational efficiency of the device. The input from the sensors would be inputted into a central processing unit which would enable the cleaning

apparatus to learn the geometric configuration of the aquaculture cage 1. The central processing unit would either be carried on board the cleaning apparatus 4 or located on a floating platform above the water that is electrically tethered to the cleaning apparatus.

Figure 6 shows a single brush head 20A, brush heads 20B and 20C are identical to brush head 20A. The brush head includes a central hub 24 for attaching the brush head to the motor output shaft contained with the unit housing 14. Circumferentially located and attached to the hub 24 is a plurality of propeller blades 26. The propeller blades 26 serve to propel the head or heads in a forward or reverse direction, while maneuvering the cleaning apparatus 4. In addition, the propeller blades 26 create a fluid flow jet that helps to flush the debris away from the screen. The opposite end of each propeller blade 26 is attached to a radially inwardly directed surface of a ring 28. A plurality of flexible hook shaped fingers 32 extend from the ring 28 in a direction perpendicular to the radially directed inward surface. The flexible hook shaped fingers 32 are located about the entire circumference of the ring. The flexible hook shaped fingers 32 are ideally made from a rubber type material with good wear and flexible characteristics such as polyurethane, thermoplastic elastomers, silicones and rubbers. Where the flexible hook shaped fingers 32 are made from a thermo plastic elastomer it should have a durometer hardness of 40 to 90 on the A shore scale. In general, the flexible hook shaped fingers will have a hardness of less than 75 on the A shore scale. As shown in Figures 4 and 6 the flexible hook shaped fingers are configured as separate strips, each strip being radially spaced from one another. The flexible hook shaped

fingers 32 between adjacent strips 36 are staggered from one another about the perimeter of the ring 28.

Figure 7 illustrates a brush head 20A having a ring 28 which includes a plurality of pins 34 placed about its circumference. Pins 34 are sized and configured to mate with complimentary holes formed on each strip 36.

Figure 8 is a side view of the flexible hook shaped fingers 32 prior to installation. The flexible hook shaped fingers 32 are formed on the elongated strip 36 that can be formed to the appropriate length. Once cut or formed to the proper length, the strip 36 is mounted on ring 28. A number of holes 38 on each strip 36 are brought into alignment with pins 34 on ring 28. Figure 9 is an enlarged view of the circled section "B" in Figure 8 with flexible hook shaped finger 32 depending therefrom.

Figures 10A through 10D show the interaction of a single flexible hook shaped finger 32 with a screen strand 7 as it approaches the strand 7, engages the strand 7, and releases the strand 7. The flexible hook shaped finger 32 includes a first longer leg portion 40 that is attached to the strip 36 at one end and transitions to a generally "U" shaped portion 42 at the opposite end of the first longer leg portion 40. The opposite end of the "U" shaped bend portion 42 transitions into a second shorter leg portion 44. The other end of the second shorter leg portion 44 terminates in a rounded tip 46. Within the "U" shaped bend portion 42, a "U" shaped channel 48 is formed. Figure 10A shows the flexible hook shaped finger 32 as the tip 46 comes into contact with a single strand 7. Figure 10B shows the strand 7 located within the "U" shaped channel 48. In this position, the flexible hook shaped finger 32 has

been elastically deformed and the "U" shaped channel 48 expanded such that the strand 7 comes into frictional engagement with leg portions 40 and 44 as well as the "U" shaped channel 48. This mechanical contact of the flexible hook shaped finger 32 and the strand 7 acts to clean both sides of the strand 7, hence the screen, simultaneously. As the brush head continues in its rotary path the flexible hook shaped finger 32 will continue to deform as shown in Figure 10C. In this position, the "U" shaped portion is elastically deformed into a position where the U-shape is substantially straightened while still maintaining an engagement with strand 7. Figure 10D shows the relationship between the flexible hook shaped finger 32 and the strand 7 just prior to the release of the flexible hook shaped finger 32 from the strand 7. In this stage of the cleaning action the flexible hook shaped finger 32 has been elastically deformed and substantially straightened. Just prior to release, the tip 46 of the finger 32 remains in contact with strand 7. The process continues with each finger 32 on the brush head continuously engaging pluralities of strands 7 on the screen 6. The cleaning apparatus 4 continues to move about the cage 1 until the screen surfaces have been cleaned.

In another embodiment, a scrubber structure 70 can be used as shown in Figures 11A and 11B. The scrubber structure 70 is constructed from a rigid frame 72 having a plurality of flexible hook shaped fingers 32 depending from a plurality of elongated strips 36 that attach to the rigid frame 72. In this embodiment, attachment to the frame can be by use of pins extending between the side walls 76 and 78 of the frame or a backing plate 80 can be integrated into the frame. At a first end 82 of the frame 72 is a ballast weight 84 that

permits the sinking of the scrubber structure. Lines 86 are positioned along a second end 88 of the frame to allow for the controlled lowering of the scrubber structure into the water and lifting therefrom. Fins 90 have a front surface 92 that use the density of the water to push the scrubber structure against a screen while the structure is being lowered. The rear surface 94 uses the density of the water to pull the scrubber structure away from a screen while the structure is being lifted. As with the previous embodiment, the fingers 32 are used to engage the screen for cleaning purposes.

In operation, the scrubber structure 70 can be lowered by an individual standing above the surface of the water who is holding on to the lines 86. The ballast weight is constructed and arranged to have sufficient weight to overcome any buoyancy of the scrubber structure 70. As the scrubber structure 70 is lowered, fins 90 have a front surface 92 using the density of the water to push the scrubber structure against a screen wherein the fingers 32 are used to engage the screen for cleaning purposes as fully described in the previous embodiment. When the scrubber structure 70 is lifted, the rear surface 94 of the fins 90 uses the density of the water to pull the scrubber structure away from the screen. The operator can then reposition over the next area to be cleaned and repeat these steps.

Figure 12 shows a cleaning apparatus including a scrubber 99 that removes fouling on aquaculture cages, the scrubber being tethered to a tractor drive 112 that advances the scrubber 99 around the cage. The scrubber 99 includes a guard bumper 100. Guard bumper 100 encompasses the radial periphery of the scrubber wheels. Guard Bumper 100 may be hollow for enacting positive buoyance on the scrubber 99. The hollow guard bumper 100

formed from 2.25 inch diameter .065 inch wall aluminum tubing. The surface of at least a portion of scrubbing wheels are recessed relative to the guard bumper for preventing bunching of the net as the scrubbing wheels rotate.

A forward bar 104 is secured to outside of the outer surface of the guard bumper 100. The forward bar 104 may be situated in a variety of different positions and orientations about the guard bumper 100. Preferably, the forward bar 104 is V-shaped. Forward bar 104 may be secured at a point 121 to one of a first end of a tethering line 120 and a weight member 102. An interior wheel circumventing bar 108 is secured to the inside of outer surface of the guard bumper 100. A stabilizing bar 110 is secured at two points of the outer surface of the guard bumper 100. A component housing member 111 is secured at a central point 113 of a first stabilizing bar 110 and a central point 113 of a second stabilizing bar 110.

Component housing member 111 may be positively buoyant, negatively buoyant or neutrally buoyant. When the component housing member 111 is positively buoyant or negatively buoyant, the scrubbing wheels can be tilted downwards and upwards, respectively, for causing contact with the aqueous cage.

The instant invention includes a housing 14 and component housing member 111 containing, inter alia, a battery and a gear motor drive. The housing 14 and the component housing member 111 can include a pressurized volume that visually or electrically demonstrates and identifies a sealed system.

FIG. 13 shows an angled shim 132 coupled between a main drive shaft 130 and propeller blade 26 of the scrubbing wheel. Angled shim 132 serves to create

wobble as the propeller blade rotates, the wobble can be used to overcome and cross structure. Angled shim 132 causes the scrubbing wheel to be tilted across its diameter for improved cleaning near center and improved movement across structure, such as door frames, fasteners, and steep construction surface angles, or corners. In one preferred embodiment, angled shim 132 introduces ¾ inch tilt across the scrubbing wheel diameter to overcome a 1 ½ inch high 90° door recess.

FIG. 14 shows propeller blade 26 mounted off center 134 of the drive axis 130 for a one hundred eighty degree (180°) synchronous offset for scrubbing the clearance zone 144 between the wheels, the clearance zone 144 represented as line A in FIG. 16. The synchronous offset results in wiggle of the scrubbing wheel. In an embodiment of the instant invention, mounting the scrubbing wheels ¾ inches to 1 ½ inches off center improves cleaning performance and improves mobility to climb across angled surfaces.

FIG. 15 shows the scrubber wheel tilted about its diameter. Forward bar 104 includes two apertures 160. Each aperture 160 is calibrated to permit attachment of a member 162. Member 162 interfacing about aperture 160 permits forward and backwards tilt of the scrubber wheel about the guard bumper 100. Member 162 can releaseably secure about aperture 160 to maintain tilt of the scrubber wheel about the guard bumper 100.

FIG. 16 shows the two scrubber wheels 99, each scrubber wheel 99 tilted about its diameter. Member 138 secures at a first point to the guard bumper outer surface 140. Member 138 secures at a second point to the housing 142 Member 138 permits outward tilt from center. Member 138 can releaseably maintain outward tilt of the scrubber wheel.

FIGS. 17A and 17B show a tractor drive 112 including at least two wheels 114, each wheel having opposing lips 122 that engage a rail, a belt 124 that rotates about the wheel cavities 121 for moving the tractor drive 112 about the railing 146. Axil 156 engages wheel 114 for permitting wheel 114 to rotate. Axil 156 secures to the first end of a plate 131. Arm 126 is affixed at a proximal end 129 to plate 131, and a pulley 150 is affixed at a distal end 127 of the arm 126. The pulley 150 permits the tethering line 120 to move across the pulley 150 when the tethering line 120 is let in and let out about the spool 132.

Axil 158 is rotatably driven by a motor 130. Motor 130 is constructed and arranged to rotate the spool 132. Arm 148 controls the engagement of the motor 130 to axil 158 and spool 132.

The tethering line 120 (Figures 12 and 17A) being secured on a second end to a winch 164 having a spool 132. Winch 164 rotates a spool 132 constructed and arranged for rotatably bringing in and letting out the tethering line 120.

Shown in FIGS. 18 thru 20B is a particular embodiment of the cleaning apparatus 4 having two cleaning units 200 constructed and arranged to move on a two-axis gimbal for orientating the cleaning units 200 relative to a net at various levels of rotation. Each cleaning unit 200 includes a first axis support member 212 having first axis projections 204 that pivotably mate to two first axis apertures 206 on a net guard 208 creating a first level of rotation therebetween. In scrubbing operation, the first level pivots about a pitch axis P.

Furthermore, the net guard 208 includes two second axis projections 210 that mate with two apertures

on a support column 218 creating a second level of rotation therebetween. In scrubbing operation, the second level pivots about a yaw axis Y. The pitch axis will be adjusted in relation to rotation of the yaw axis Y.

The support column 218 is defined by a middle beam 220 mounted between end beams 202. The middle beam 220 includes a slot 216. The first axis support member 212 includes a gimbal limiting arm 214 that fits into the slot 216. The gimbal limiting arm 214 limits the freedom of movement of the pitch and yaw axis, and more specifically limits the movement of the cleaning units 200 about the two-axis gimbal.

In one particular design, the end beams 202 secure the component housing member 111, the component housing member 11 further disclosed herein.

The net guard 208 fits in close proximity to a cleaning brush head 20D. The net guard 208 assists in preventing bunching of the net during scrubbing operation as the scrubbing wheels rotate. In addition to preventing bunching, the net guard 208 assists in holding the net taut resulting in the scrubber advancing against the net.

As shown in FIGS. 21A thru 23B, aquaculture surface cages commonly implement handrails. The handrails are approximately one meter (1m) above the water line. In yet an additional feature of the instant invention, the cleaning apparatus includes a tractor drive designed to drivably connect to the hand rail found on the aquaculture surface cages, the tractor drive is preferably battery powered. The tractor drive shall slowly advance along the hand rail or any elongated surface. A winch is provided about the tractor drive, the winch pulling the scrubber for ascending the

underwater scrubber, the winch letting out the scrubber for descending underwater scrubber.

The cages include screens (Fig. 3) that are attached to support members 2. The support members may be formed from hollow plastic or other buoyant materials. Alternatively, the support members 2 may secure by a securement member 324 to other buoyant members 326. A platform or other cage dock 148 may be secured to the buoyant materials, including the support members and the buoyant materials. The platform supports weight and additionally allows individuals to walk around the perimeter of the cage. A rail may otherwise be attached to the support members 2.

As shown in FIGS. 21A and 21B, handrails commonly found on aquaculture surface cages 300 are on the inward side of the dock floating assembly. The handrails 302 being located on the inward side of the cage enclosure causes fouling to be pushed inside the cage by the scrubber.

As shown in FIGS. 22A thru 23B, reversing the construction of the cage dock 148 and rail 146, or constructing an additional rail outside of the dock 148 diverts the fouling away from the cage as the scrubber cleans from the outside of the cage for preventing fouling buildup inside of the cage or screen 6 (Fig. 3).

All patents and publications mentioned in this specification are indicative of the levels of those skilled in the art to which the invention pertains. All patents and publications are herein incorporated by reference to the same extent as if each individual publication was specifically and individually indicated to be incorporated by reference.

It is to be understood that while a certain form of the invention is illustrated, it is not to be

limited to the specific form or arrangement herein described and shown. It will be apparent to those skilled in the art that various changes may be made without departing from the scope of the invention and the invention is not to be considered limited to what is shown and described in the specification and any drawings/figures included herein.

One skilled in the art will readily appreciate that the present invention is well adapted to carry out the objectives and obtain the ends and advantages mentioned, as well as those inherent therein. The embodiments, methods, procedures and techniques described herein are presently representative of the preferred embodiments, are intended to be exemplary and are not intended as limitations on the scope. Changes therein and other uses will occur to those skilled in the art which are encompassed within the spirit of the invention and are defined by the scope of the appended claims. Although the invention has been described in connection with specific preferred embodiments, it should be understood that the invention as claimed should not be unduly limited to such specific embodiments. Indeed, various modifications of the described modes for carrying out the invention which are obvious to those skilled in the art are intended to be within the scope of the following claims.

CLAIMS

What is claimed is:

Claim 1. A cleaning apparatus for aquaculture screens comprising:

a brush head assembly having a plurality of hook shaped fingers constructed and arranged to engage an aquaculture screen cage element for removal of debris therefrom; and

a power output coupled to said brush head assembly for rotation of said brush head assembly about an axis of rotation.

Claim 2. The cleaning apparatus for aquaculture screens of claim 1 wherein said brush head assembly is formed from a hub coupled to an outer ring member by a plurality of blade members, said power output coupled to said head and said blade members providing directional output.

Claim 3. The cleaning apparatus for aquaculture screen of claim 1 wherein said hook shaped fingers are elastically deformable to substantially wrap around a screen cage element such that said hook shaped members remove debris from an outer side surface of the screen cage element and upon rotation of said outer ring member, said flexible hook shaped members are bent into a substantially straight portion for removing of debris along an inner side surface of the screen member.

Claim 4. The cleaning apparatus for aquaculture screens of claim 1 wherein said hook shaped fingers are formed from a thermoplastic elastomer having a durometer of 40 to 90 A shore scale.

Claim 5. The cleaning apparatus for aquaculture screens of claim 1 wherein each said hook shaped fingers are formed from a first leg portion that is attached to an elongated member at one end and transitions to a generally "U" shaped portion at the opposite end of said first longer leg portion, said opposite end of the "U" shaped portion transitions into a second leg, said first leg portion is longer than said second leg portion, said flexible hook shaped fingers being elastically deformable such that the "U" shaped portion can be transformed into a substantially straight portion under the influence of an applied force.

Claim 6. The cleaning apparatus for aquaculture screens of claim 5 wherein said second leg has a thickness that approximates the length of said second leg.

Claim 7. The cleaning apparatus for aquaculture screens of claim 2 wherein said hook shaped fingers are spaced apart along said ring member forming a first diameter.

Claim 8. The cleaning apparatus for aquaculture screens of claim 2 wherein said hook shaped fingers are spaced apart along a second ring member forming a second diameter.

Claim 9. The cleaning apparatus for aquaculture screens of claim 2 wherein said blade members are directional for advancing the motion of the brush head during rotation.

Claim 10. The cleaning apparatus for aquaculture screens of claim 9 wherein said blade members operate as a propeller.

Claim 11. The cleaning apparatus for aquaculture screens of claim 2 wherein the motion of said cleaning apparatus for aquaculture screens is articulated by controlling the rotational speed of said blade members.

Claim 12. The automatic cleaning apparatus for aquaculture screens of claim 10 wherein said propellers will propel the cleaning device at a speed of 1 to 4 feet per second.

Claim 13. The cleaning apparatus for aquaculture screens of claim 1 wherein said power output is a self-contained battery source.

Claim 14. The cleaning apparatus for aquaculture screens of claim 1 including a frame for securing said brush head assembly to at least one additional brush head assembly.

Claim 15. The cleaning apparatus for aquaculture screens of claim 14 wherein said frame includes a means for ballasting.

Claim 16. The cleaning apparatus for aquaculture screens of claim 14 wherein said frame includes a fin for directional juxtapositioning of the frame along the surface of an aquaculture screen when the frame is moved in an engagement direction.

Claim 17. The cleaning apparatus for aquaculture screens of claim 16 wherein said fin permits displacement of said frame from said the surface of the screen when the frame is moved in a disengagement position.

Claim 18. The cleaning apparatus for aquaculture screens of claim 1 including a sensor coupled to a processing unit for detection of a load barrier whereby reversing propulsion of said brush assembly allows removal from said load barrier.

Claim 19. The cleaning apparatus for aquaculture screens of claim 18 wherein said sensor is a proximity sensor.

Claim 20. The cleaning apparatus for aquaculture screens of claim 18 including at homing signal apparatus coupled to a processing unit communicating a docking position within said aquaculture screen cage and said cleaning apparatus.

Claim 21. The cleaning apparatus for aquaculture screens of claim 14 including a stationary guard secured to said frame, said stationary guard constructed and arranged to control the distal relationship between said flexible hooked shaped fingers and said aquaculture cage screen.

Claim 22. The cleaning apparatus for aquaculture screens of claim 2 wherein a central point of said brush head is mounted off-center from said axis of rotation.

Claim 23. The cleaning apparatus for aquaculture screens of claim 22 wherein a central point of said brush head is mounted ¾ inches to 1½ inches off center from said axis of rotation.

Claim 24. The cleaning apparatus for aquaculture screens of claim 2 wherein said brush head is offset at an angle relative to and perpendicular from said axis of rotation.

Claim 25. The cleaning apparatus for aquaculture screens of claim 14 wherein at least two adjacent brush heads rotate counter to each other.

Claim 26. The cleaning apparatus for aquaculture screens of claim 14 including an inner perimeter component positioned between adjacent brush heads to prevent bundling of said aquaculture cage screens during operation of said cleaning device.

Claim 27. The cleaning apparatus for aquaculture screens of claim 1 including a tractor drive means operatively associated with an elongated component secured to an upper edge of an aquaculture screen cage, said tractor drive means allowing placement of said cleaning apparatus along an inner or an outer surface of a screen cage.

Claim 28. The cleaning apparatus for aquaculture screens of claim 27 wherein said elongated component is a handrail having a tubular shaped component positioned along the inner or outer diameter of the screen cage, said tractor drive means including a self centering roller mechanism for supporting of said cleaning apparatus and a winch for raising and lowering of the cleaning apparatus by use of a tethering line.

Claim 29. The cleaning apparatus for aquaculture screens of claim 14 wherein said brush head is pivotably connected to a gimbal support structure wherein said gimbal support structure permits two levels of brush head rotation, said gimbal support structure having a middle beam interposed between a first and second end beam; a net guard having a first axis, said brush head pivotably interposed about said first axis to permit said brush

head rotation about said first axis, said net guard pivotably interposed between said first and second end beam to permit said brush head rotation about a second axis; wherein said first axis and said second axis may be 90° offset.

Claim 30. The cleaning apparatus for aquaculture screens of claim 1 wherein said power output is further defined as a brushless DC motor coupled to at least one lithium polymer battery.

Claim 31. The cleaning apparatus for aquaculture screens of claim 30 wherein said lithium polymer battery will deliver more than .12 watts per gram and 400 watts per hour.

Claim 32. The cleaning apparatus for aquaculture screens of claim 30 wherein said motor can achieve a rotor tip speed of about 1 to 4 ft/sec.

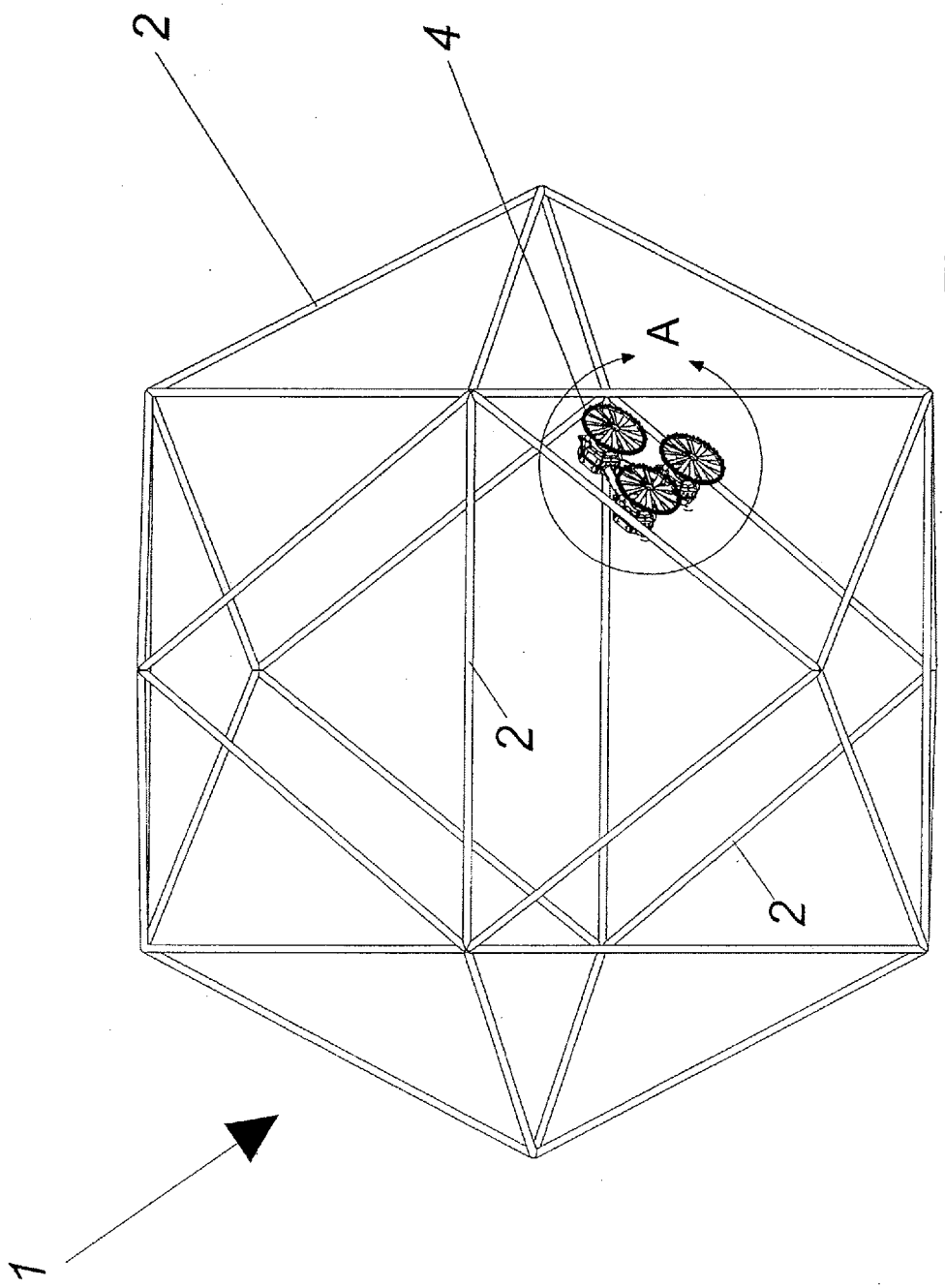



Fig 1

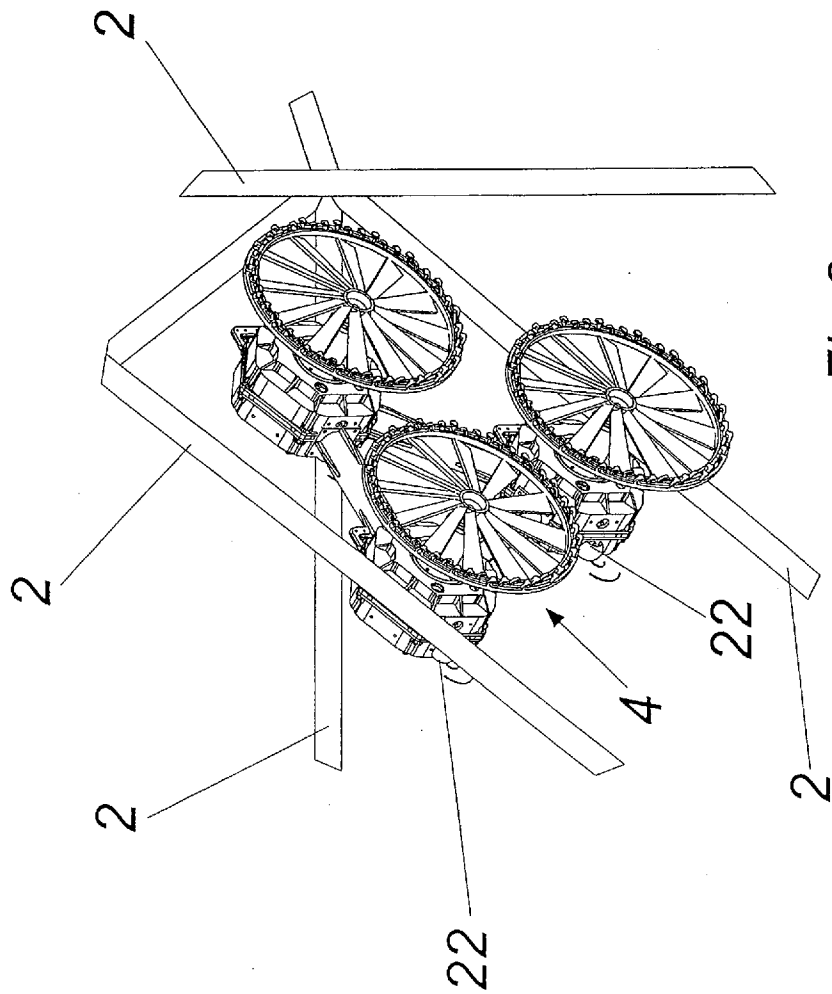



Fig 2

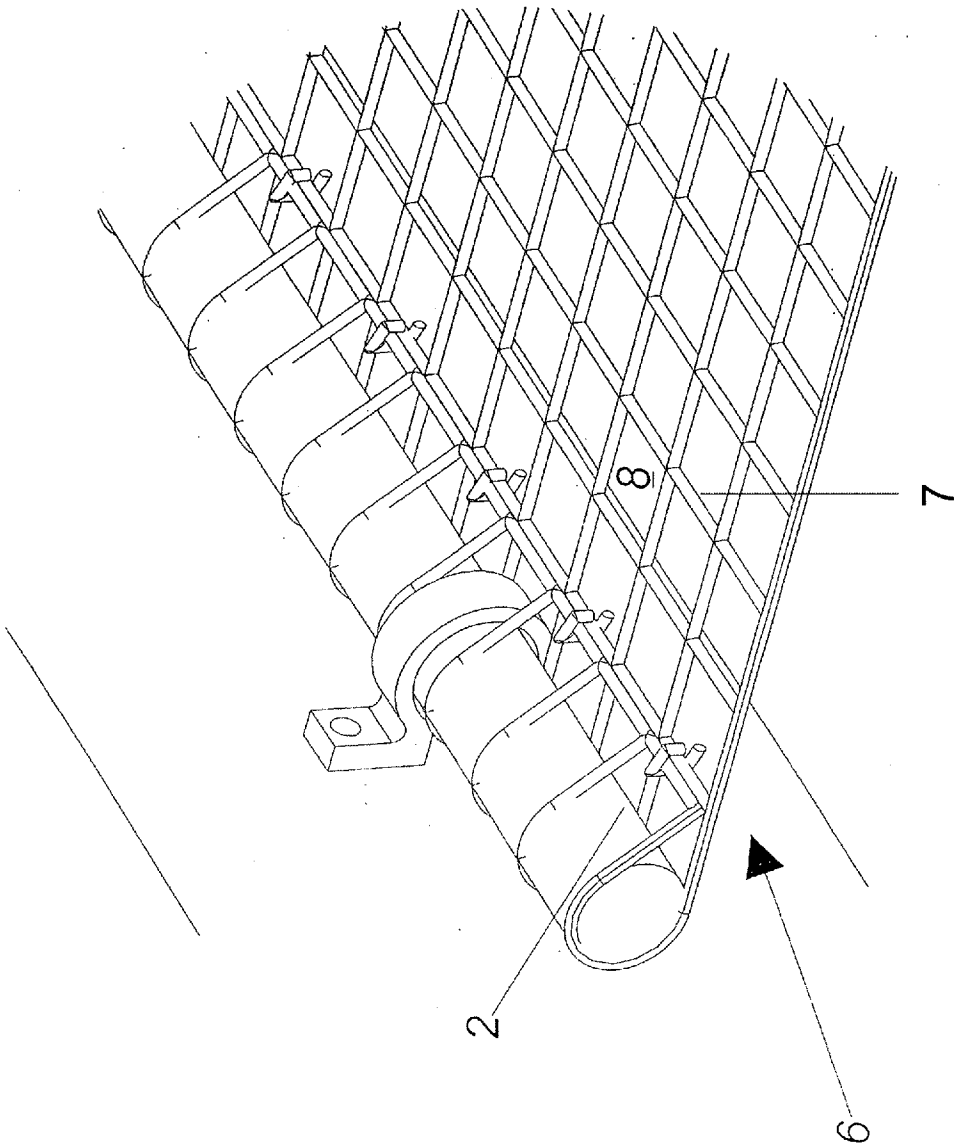



Fig. 3

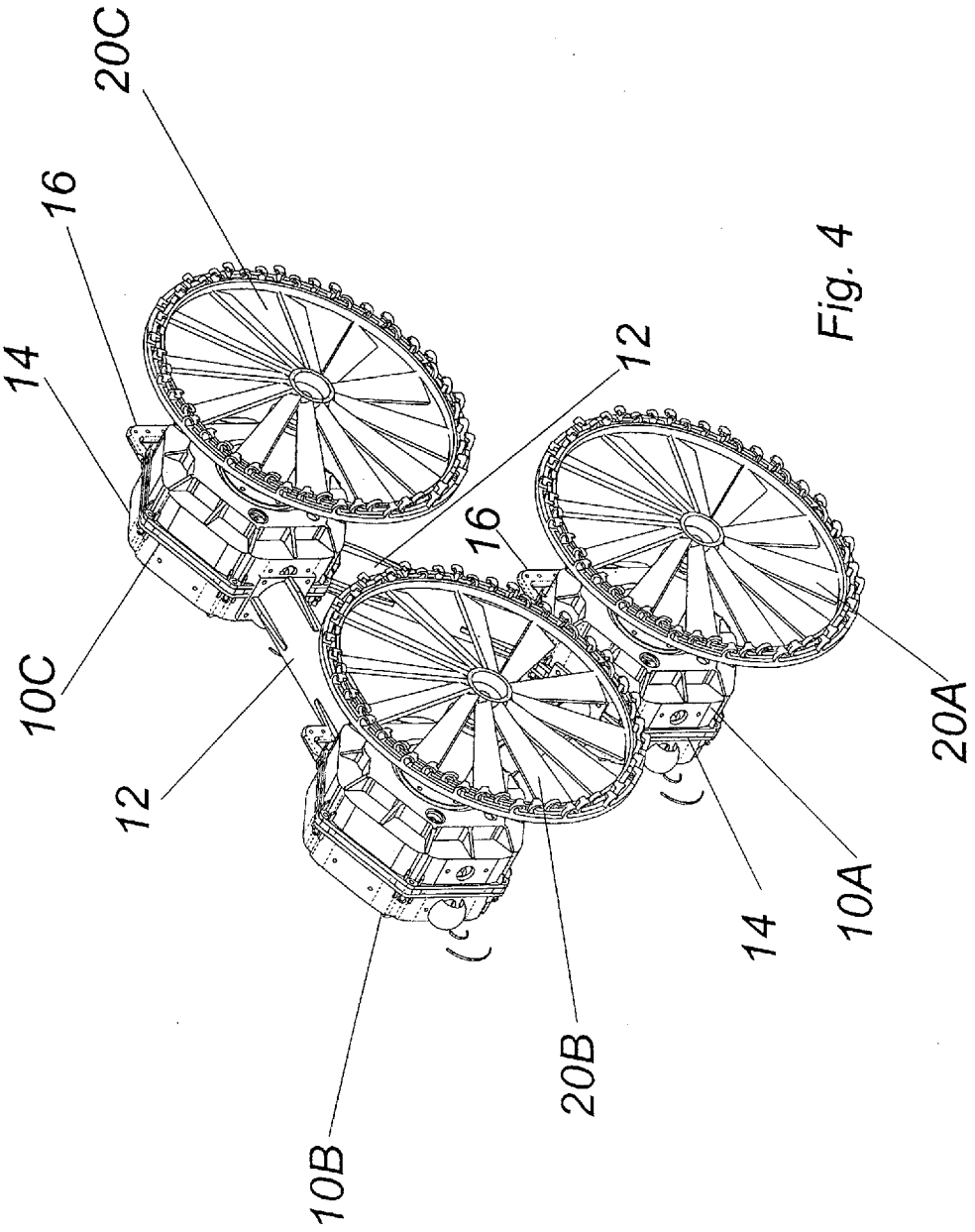



Fig. 4

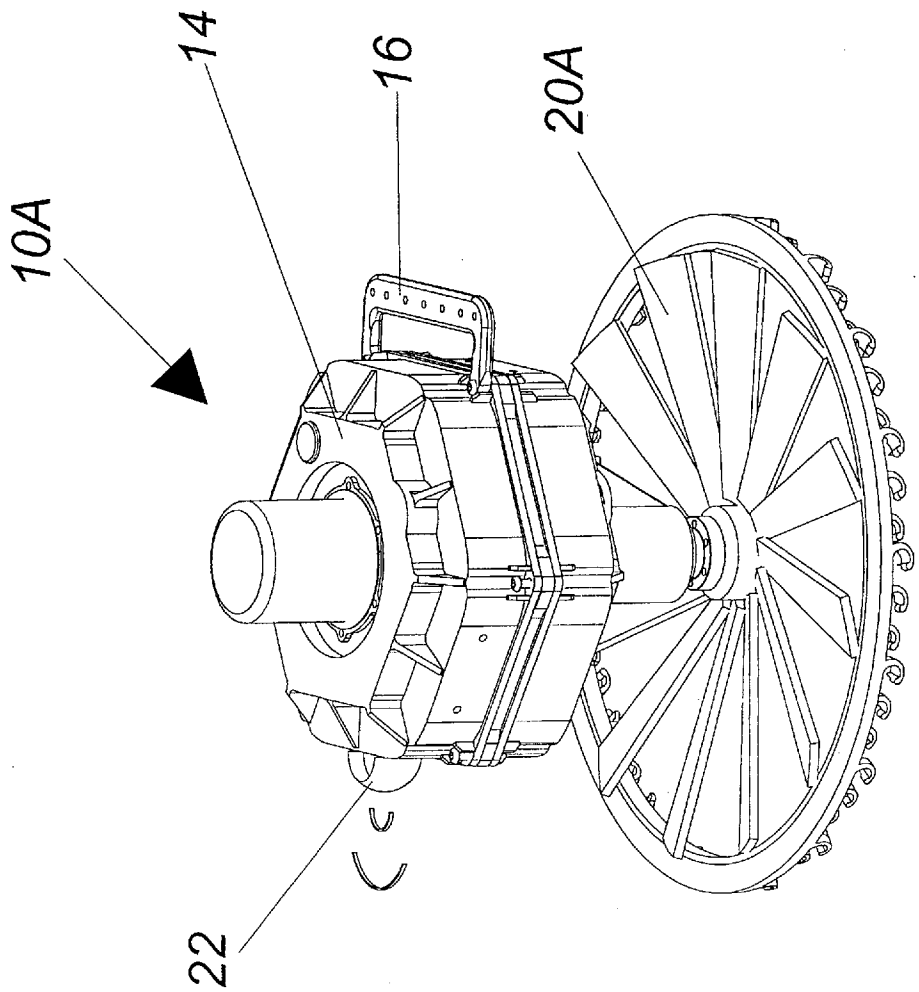



Fig. 5

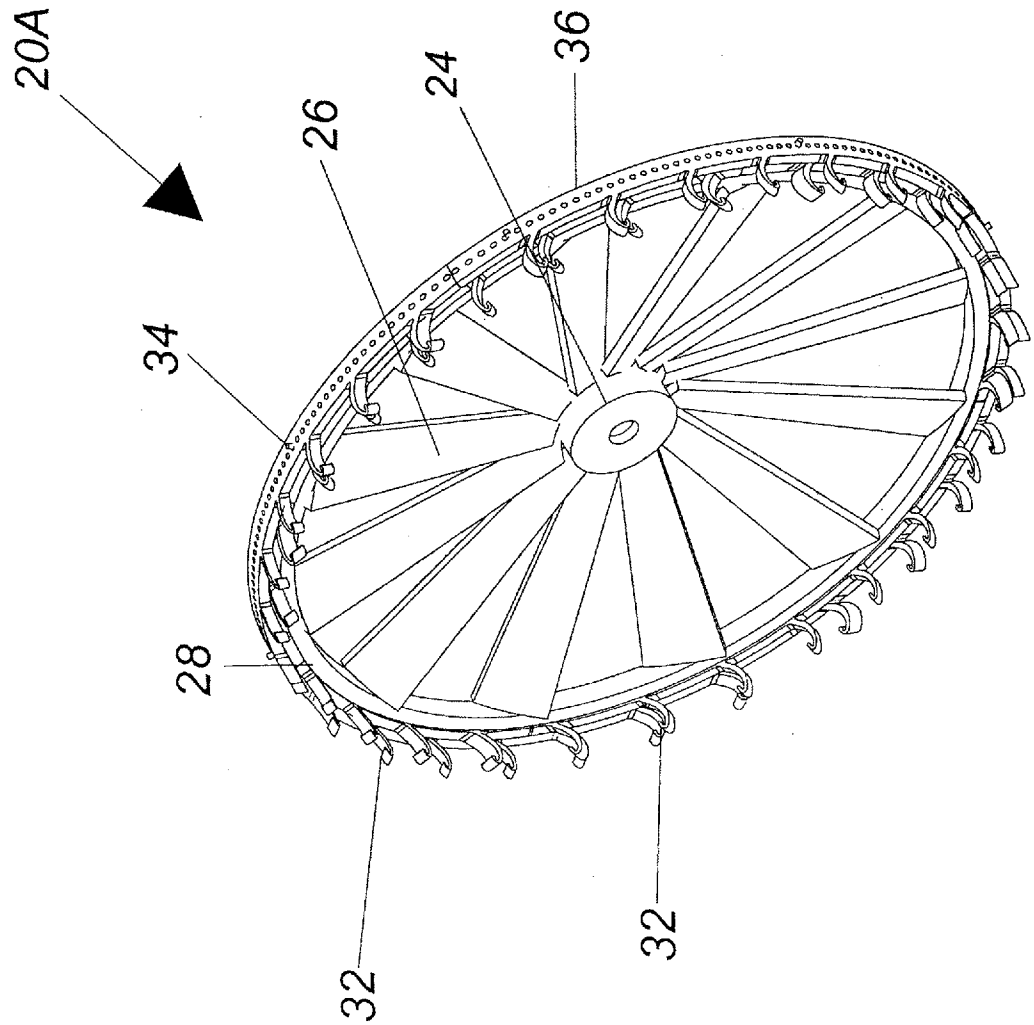



Fig. 6

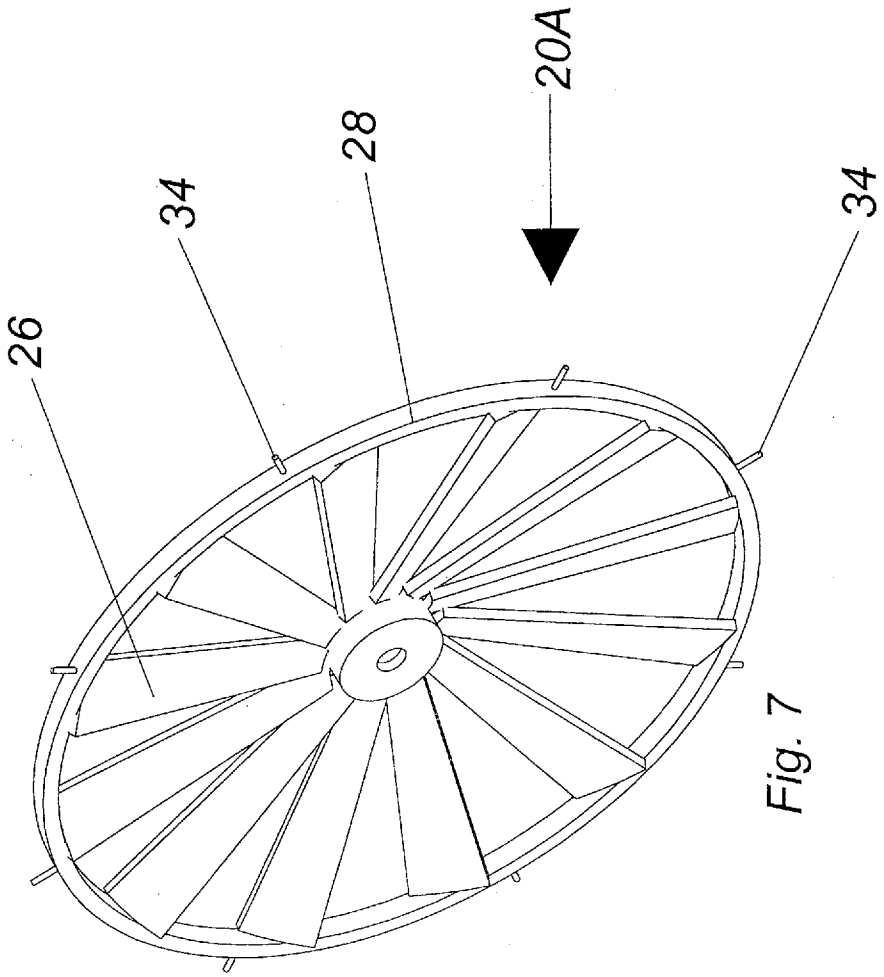



Fig. 7

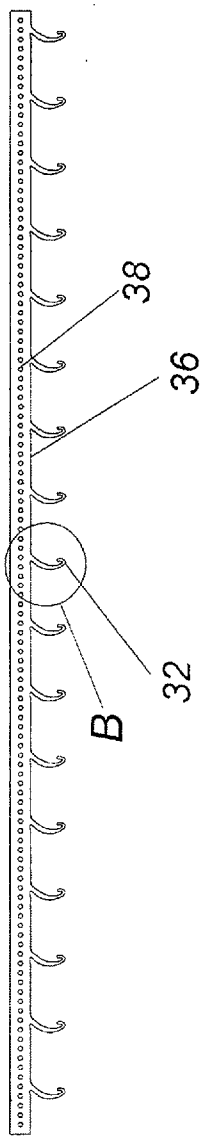



Fig. 8

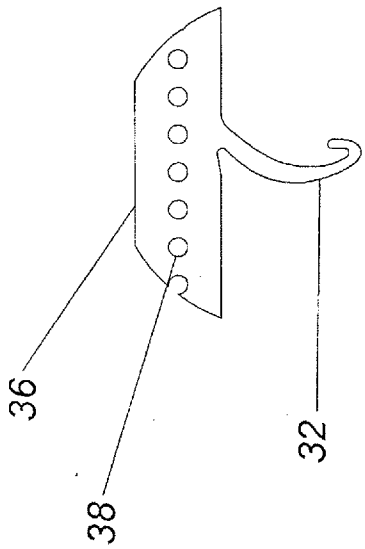



Fig. 9

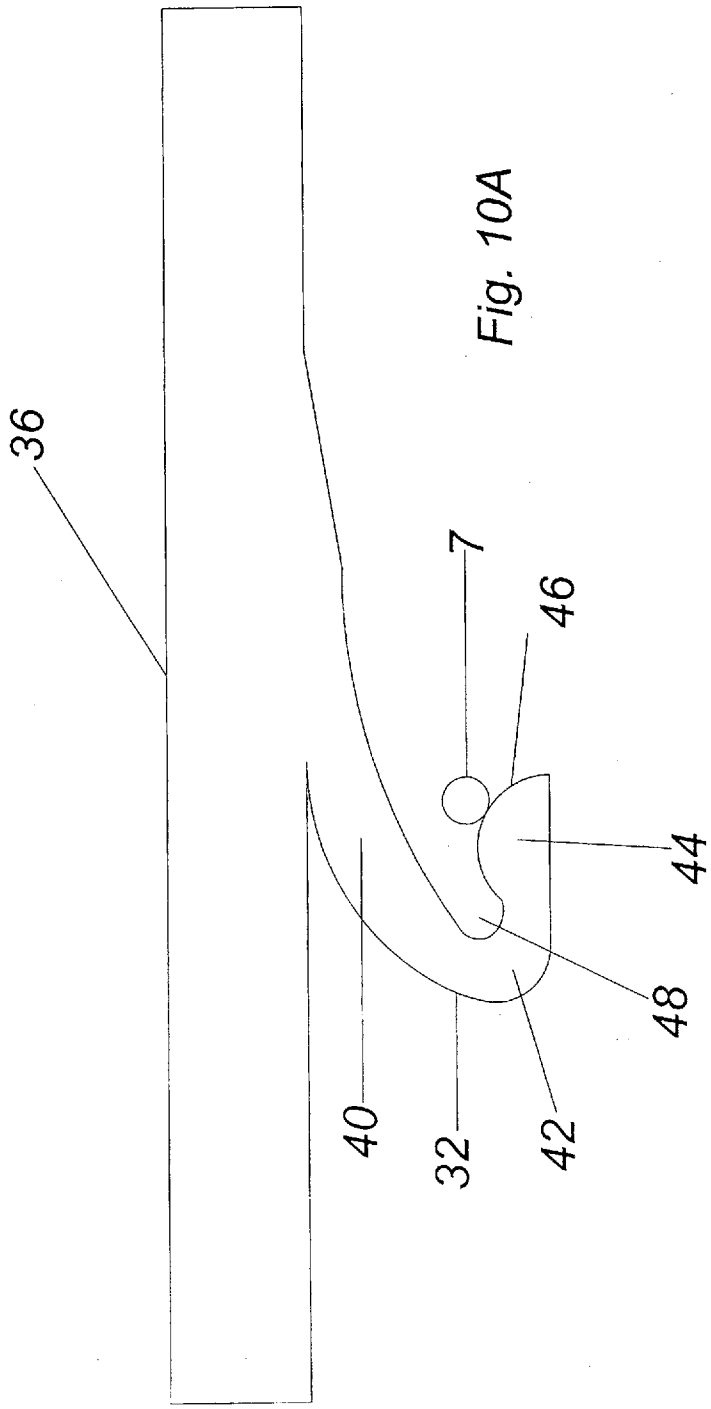



Fig. 10A

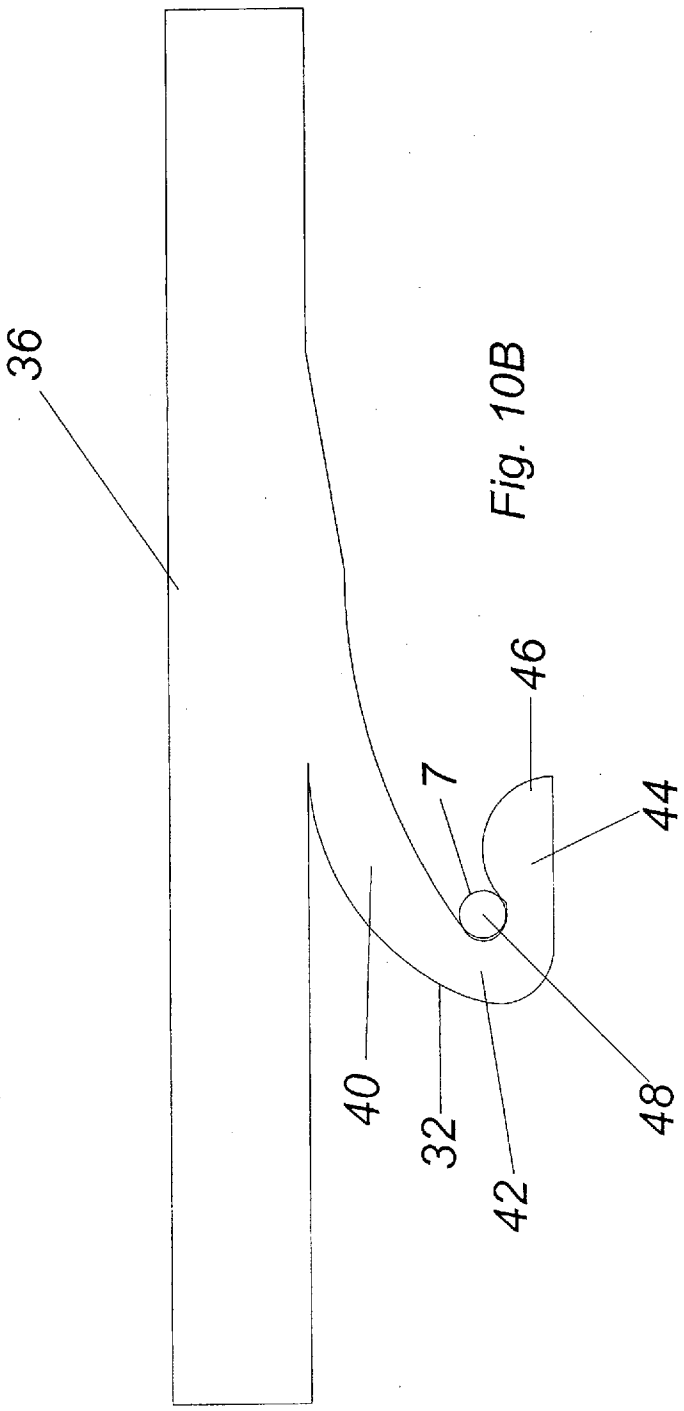



Fig. 10B

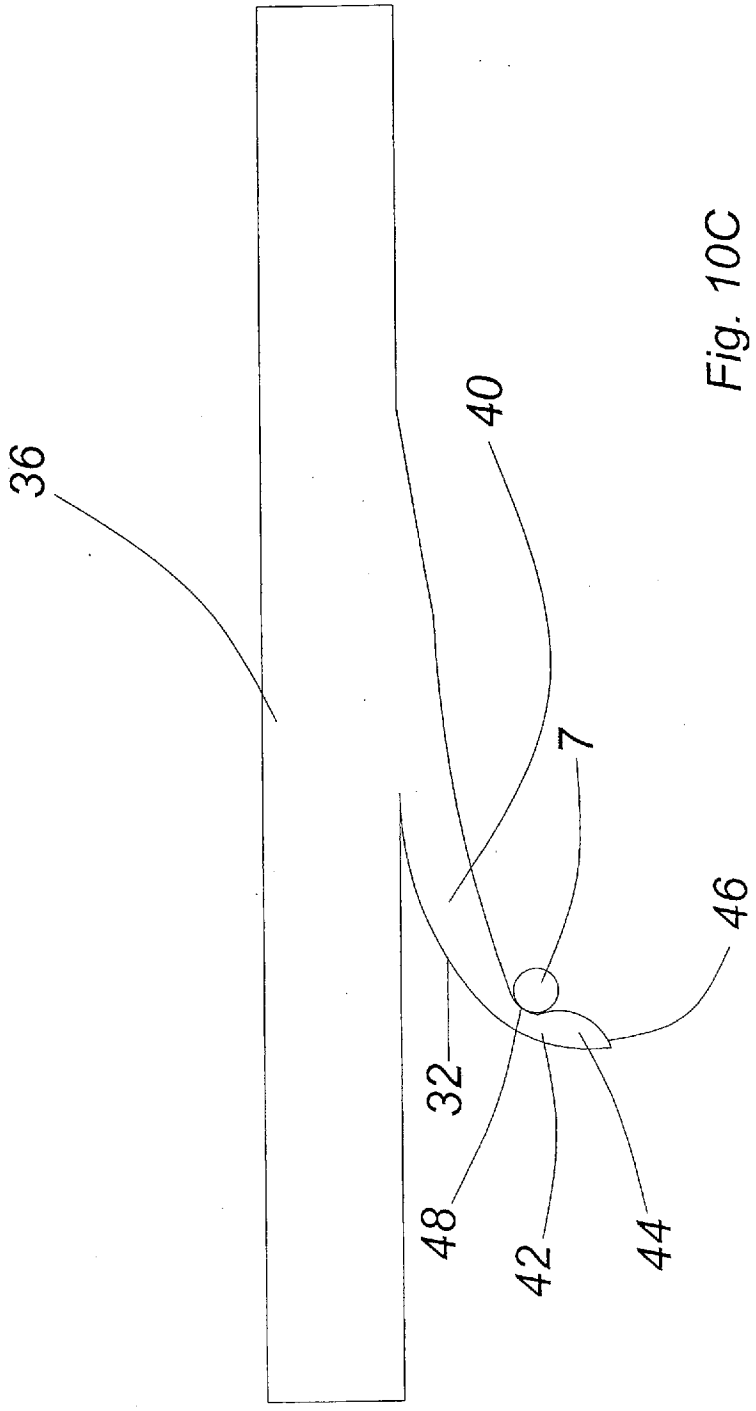



Fig. 10C

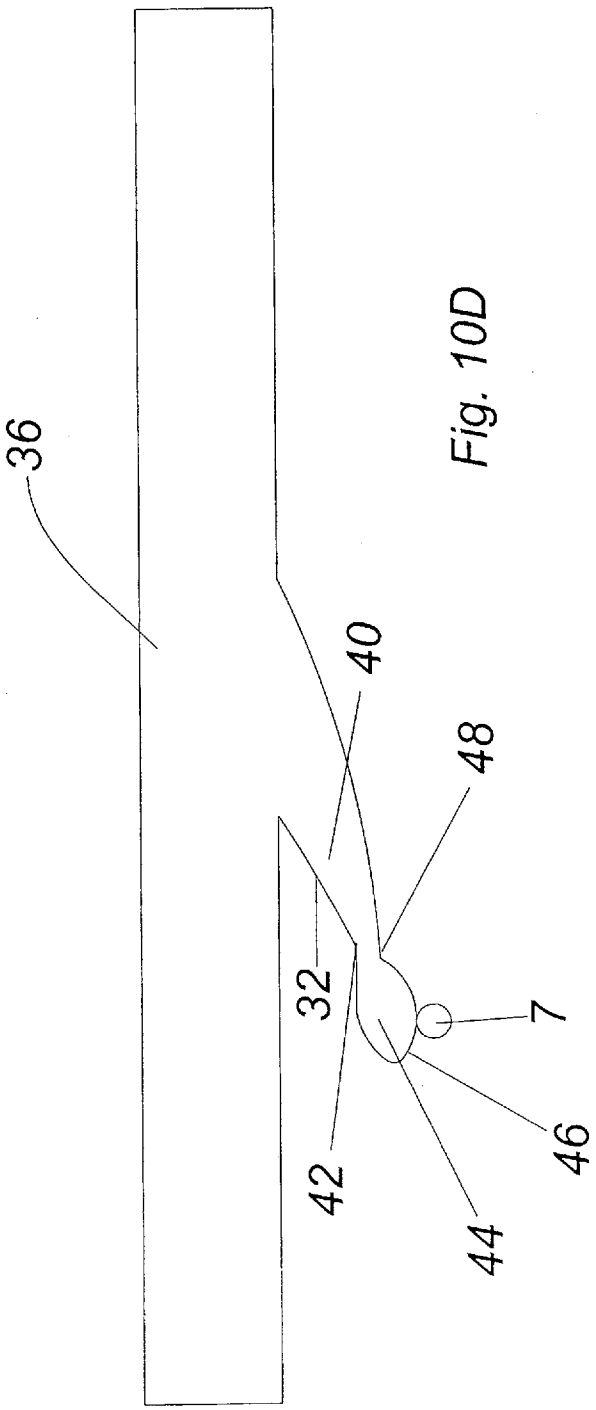



Fig. 10D

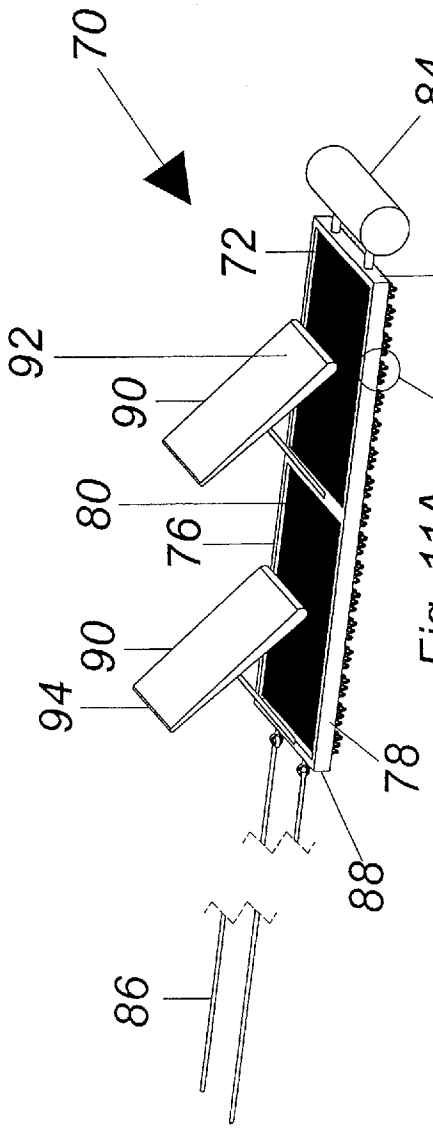



Fig. 11A

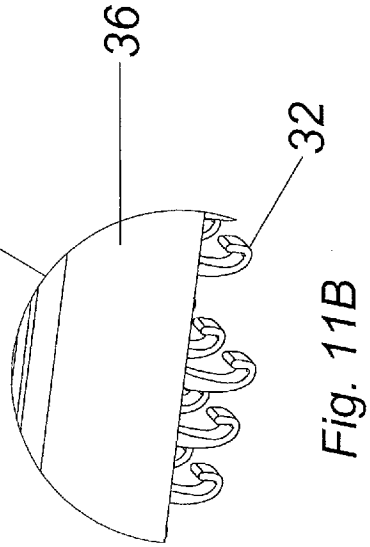
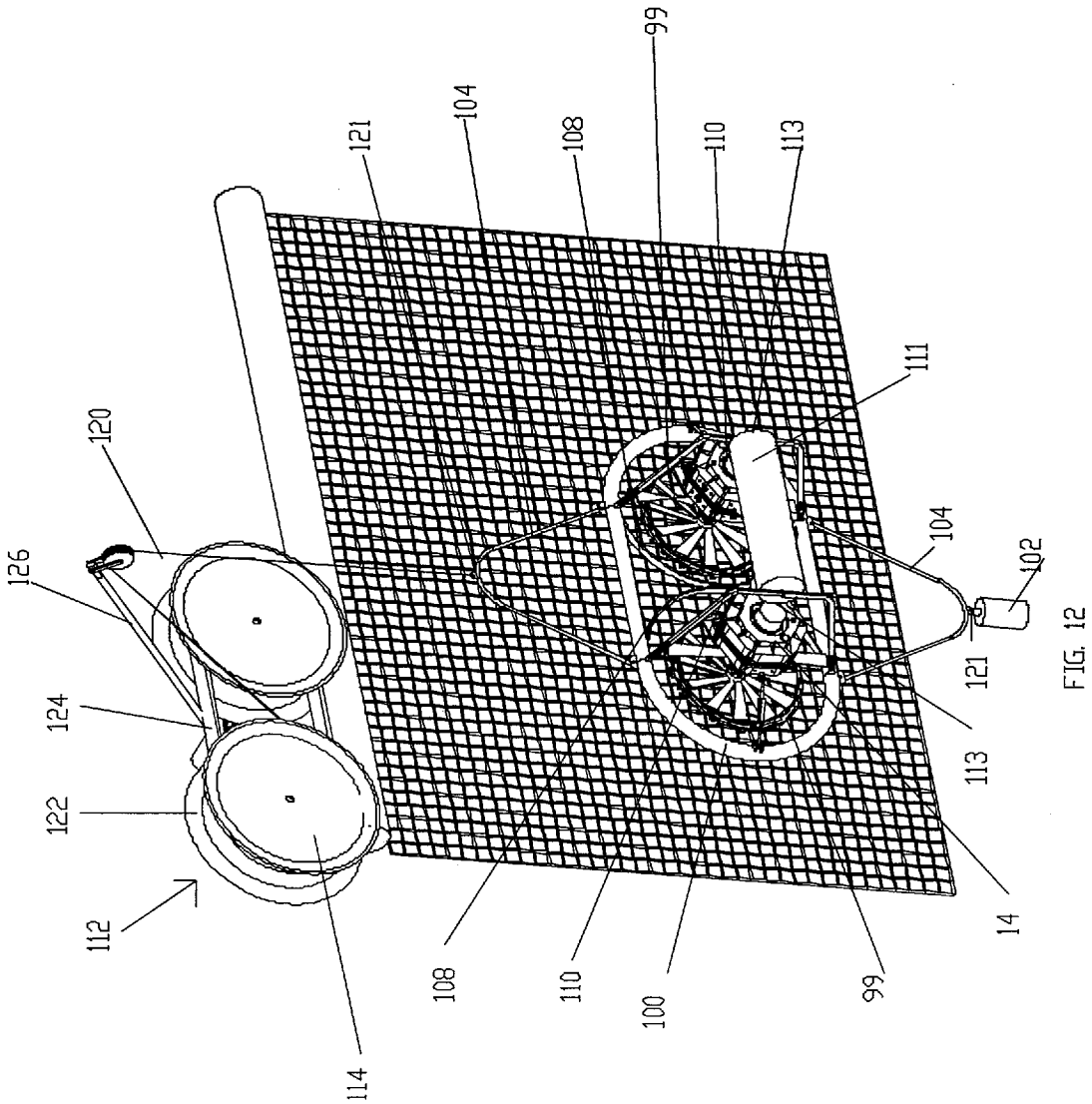



Fig. 11B


99
121
104
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114

FIG. 12

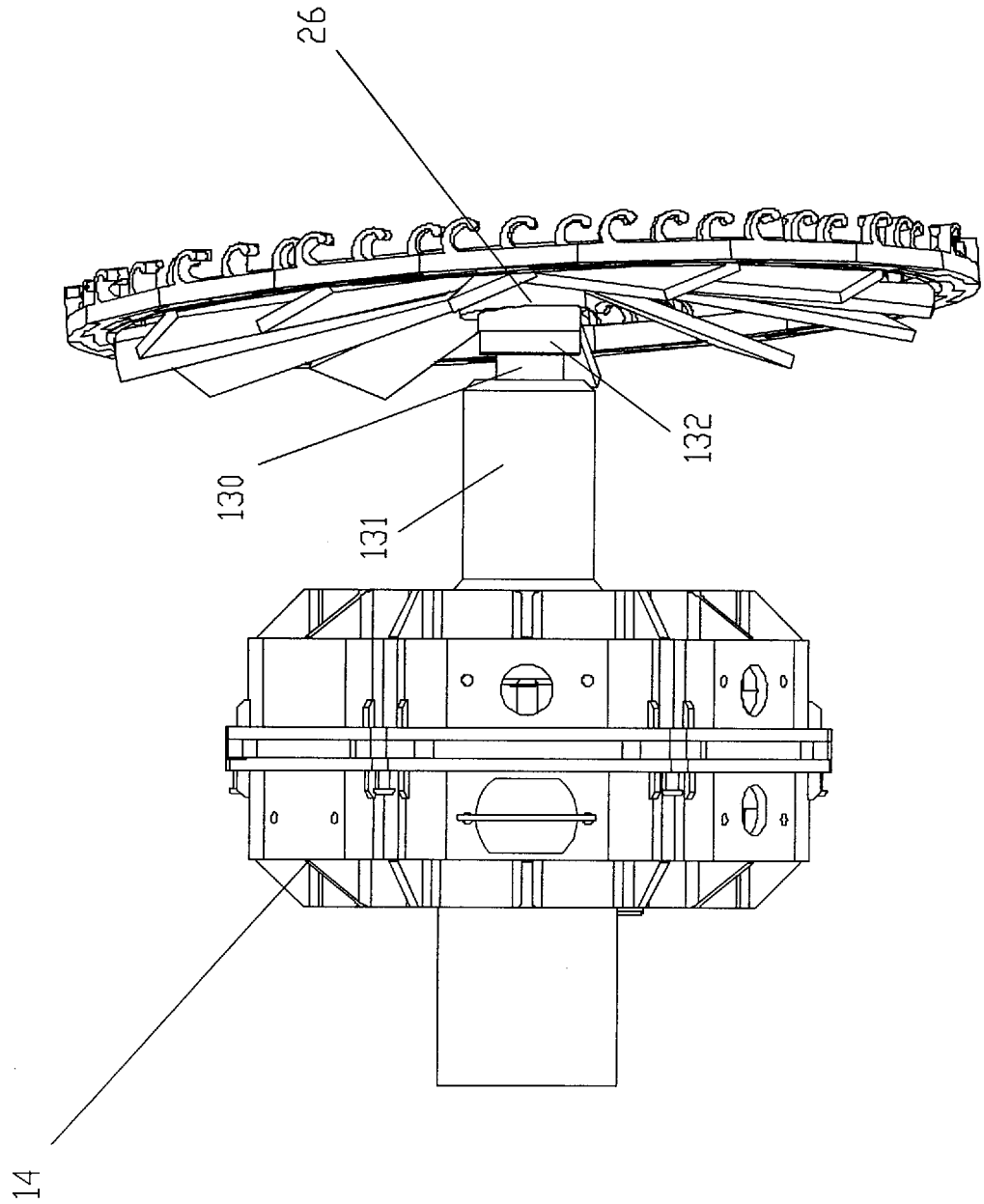



FIG. 13

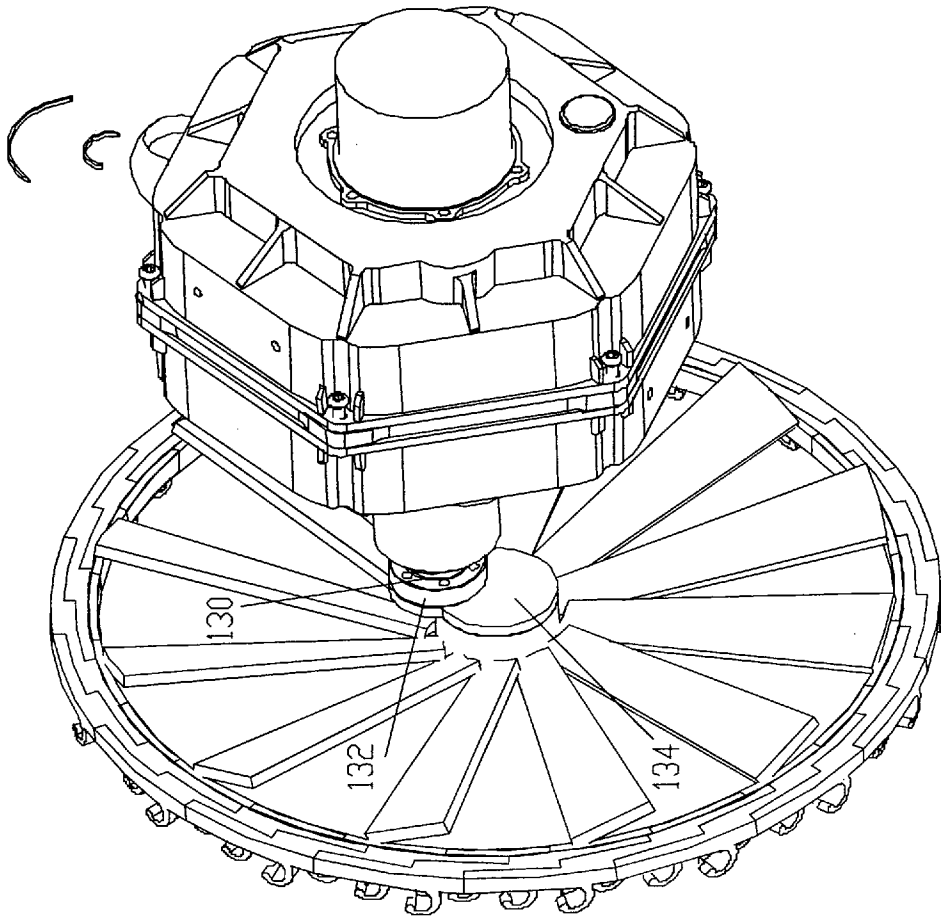



FIG. 14

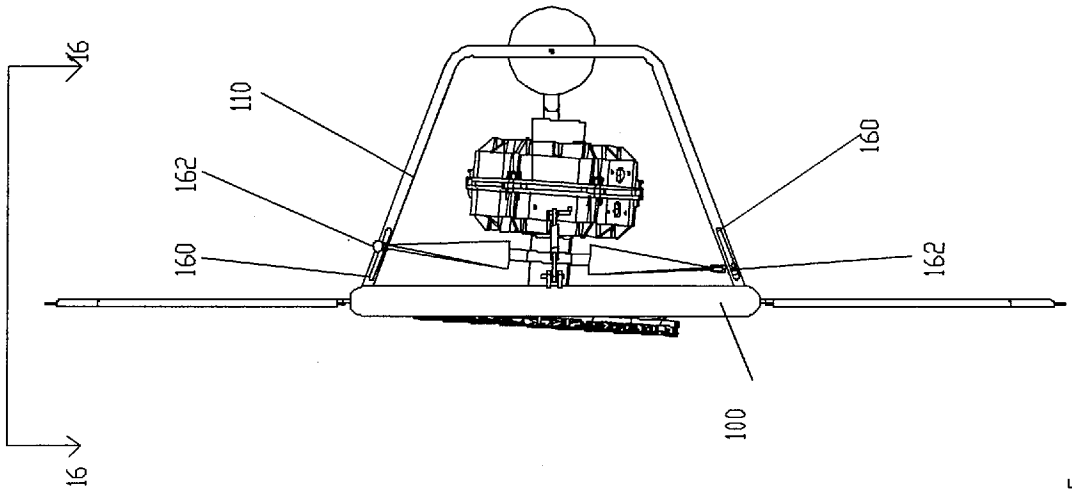



FIG. 15

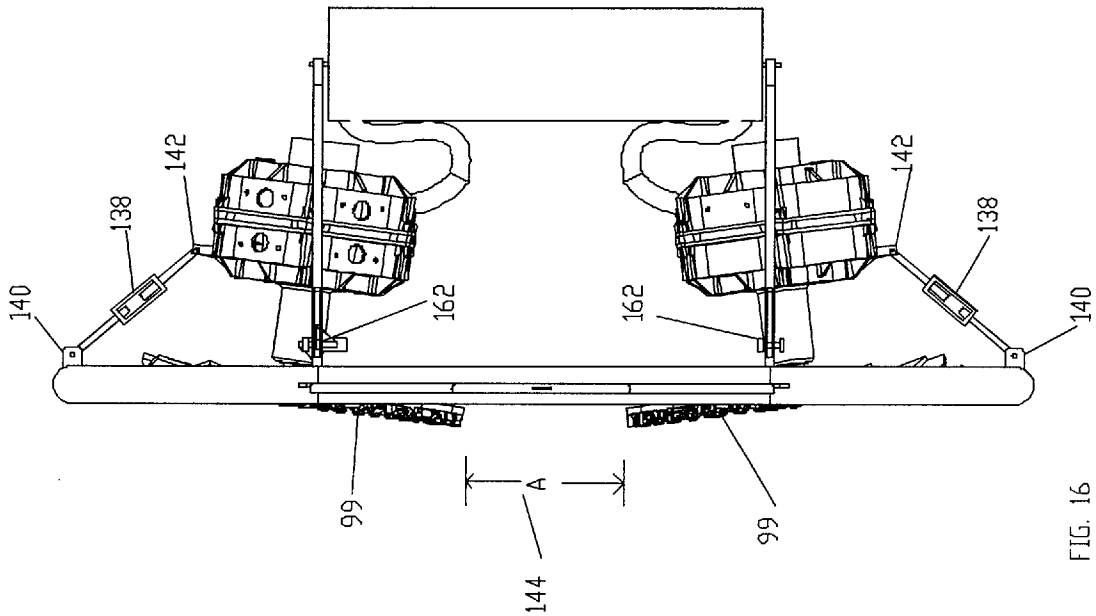



FIG. 16

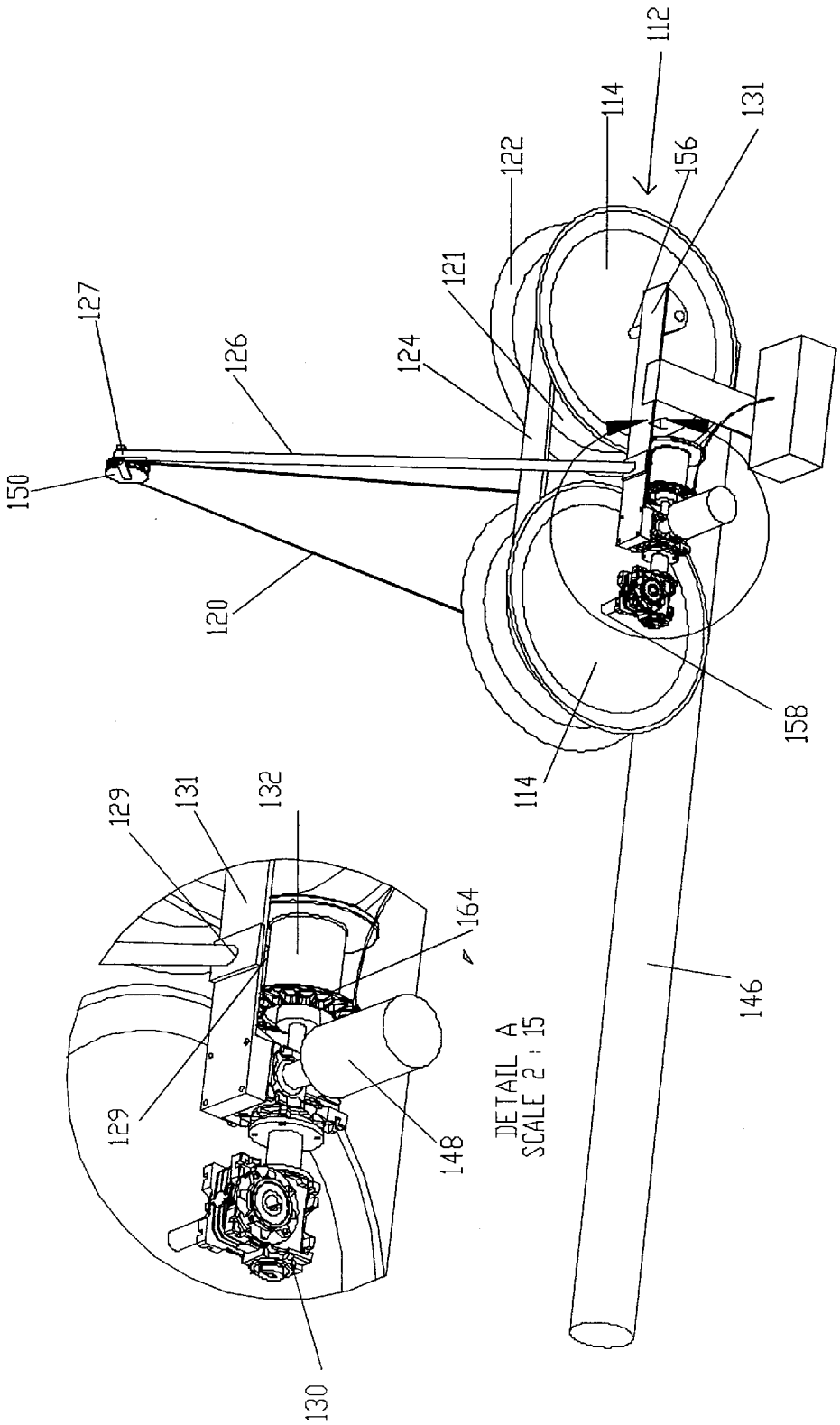



FIG. 17A

FIG. 17B

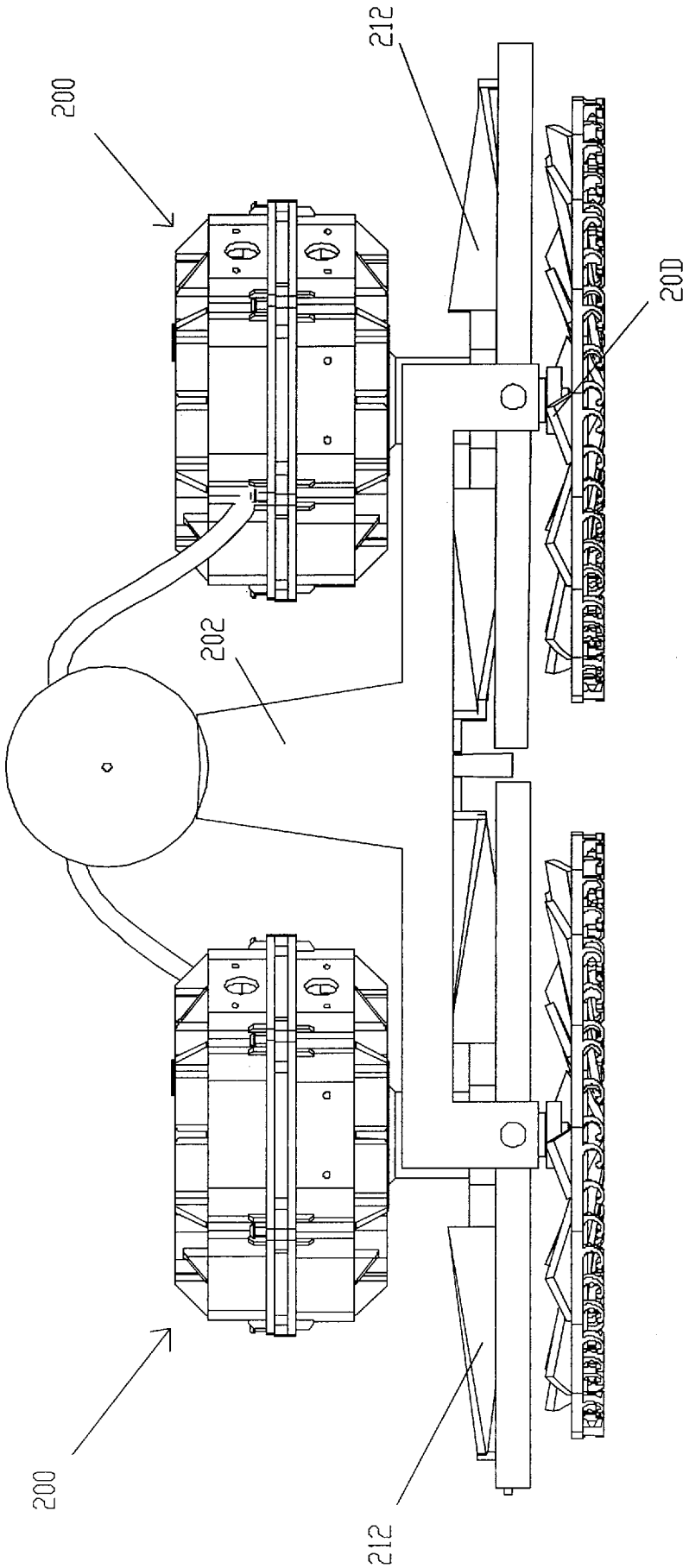



FIG. 18

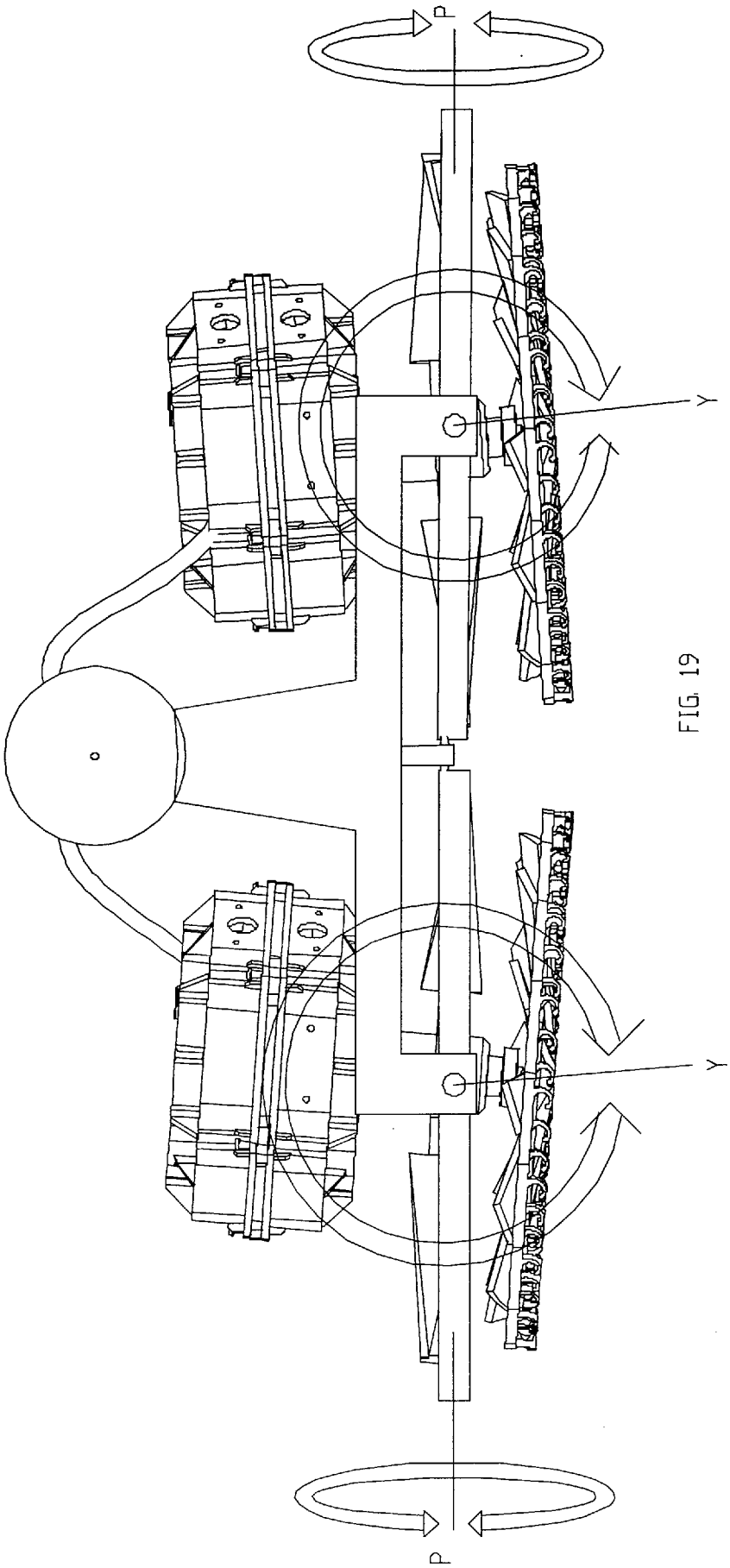



FIG. 19

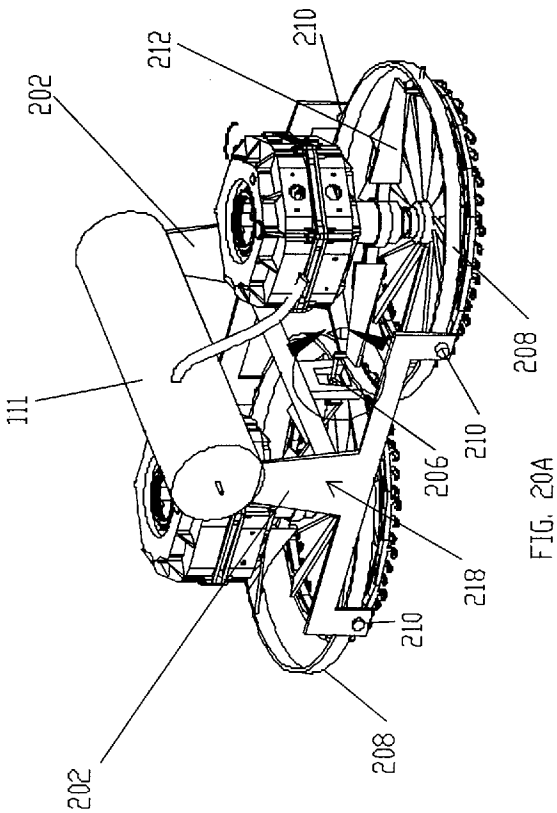



FIG. 20A

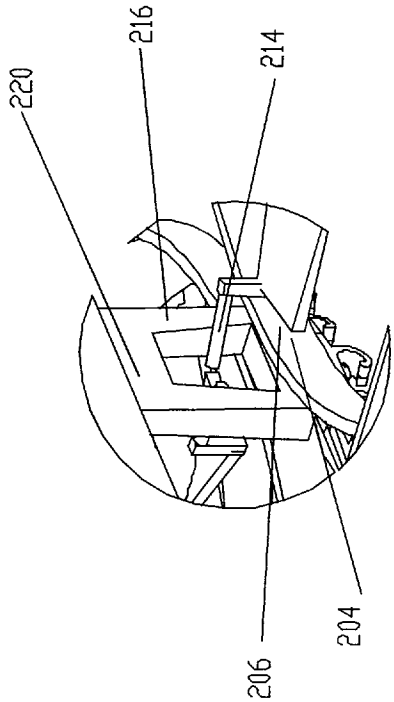
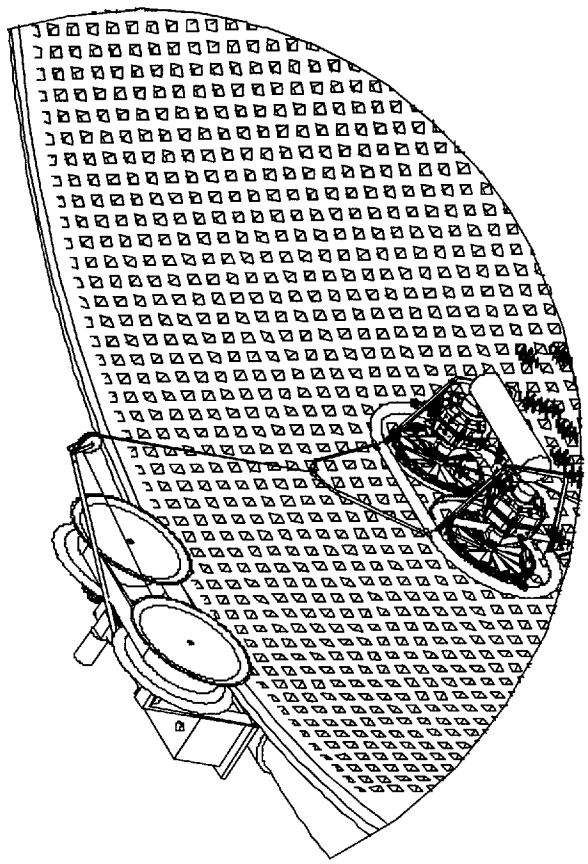



FIG. 20B

DETAIL A
SCALE 1 : 3



DETAIL D
SCALE 1 : 30

FIG. 21B

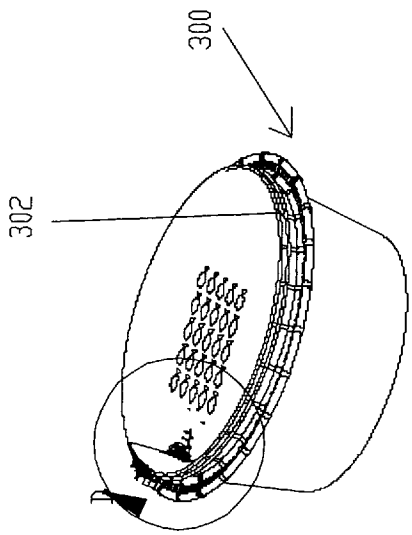



FIG 21A

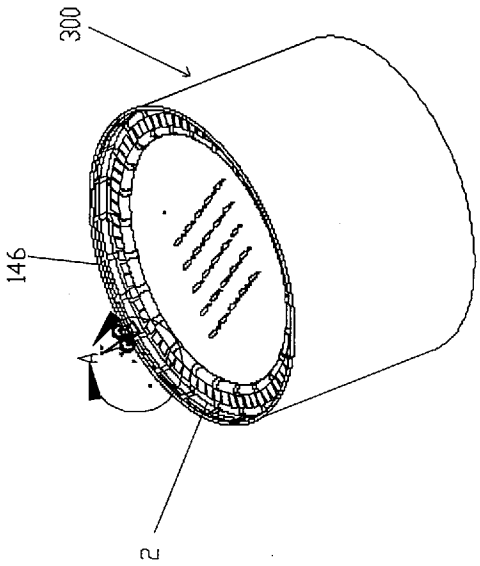



FIG. 22A

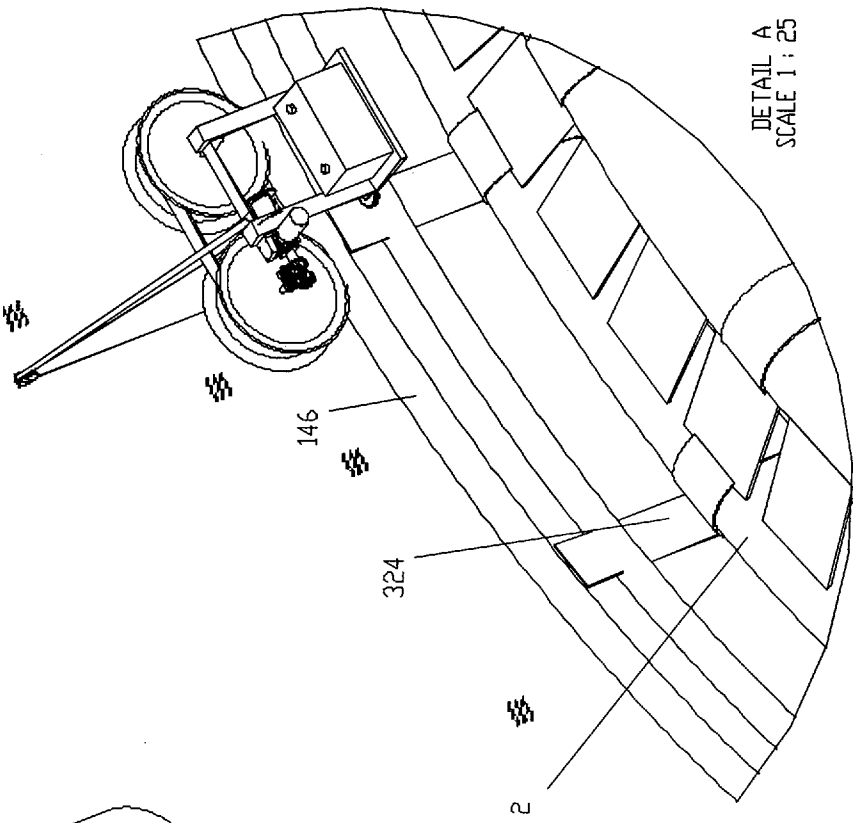



FIG. 22B

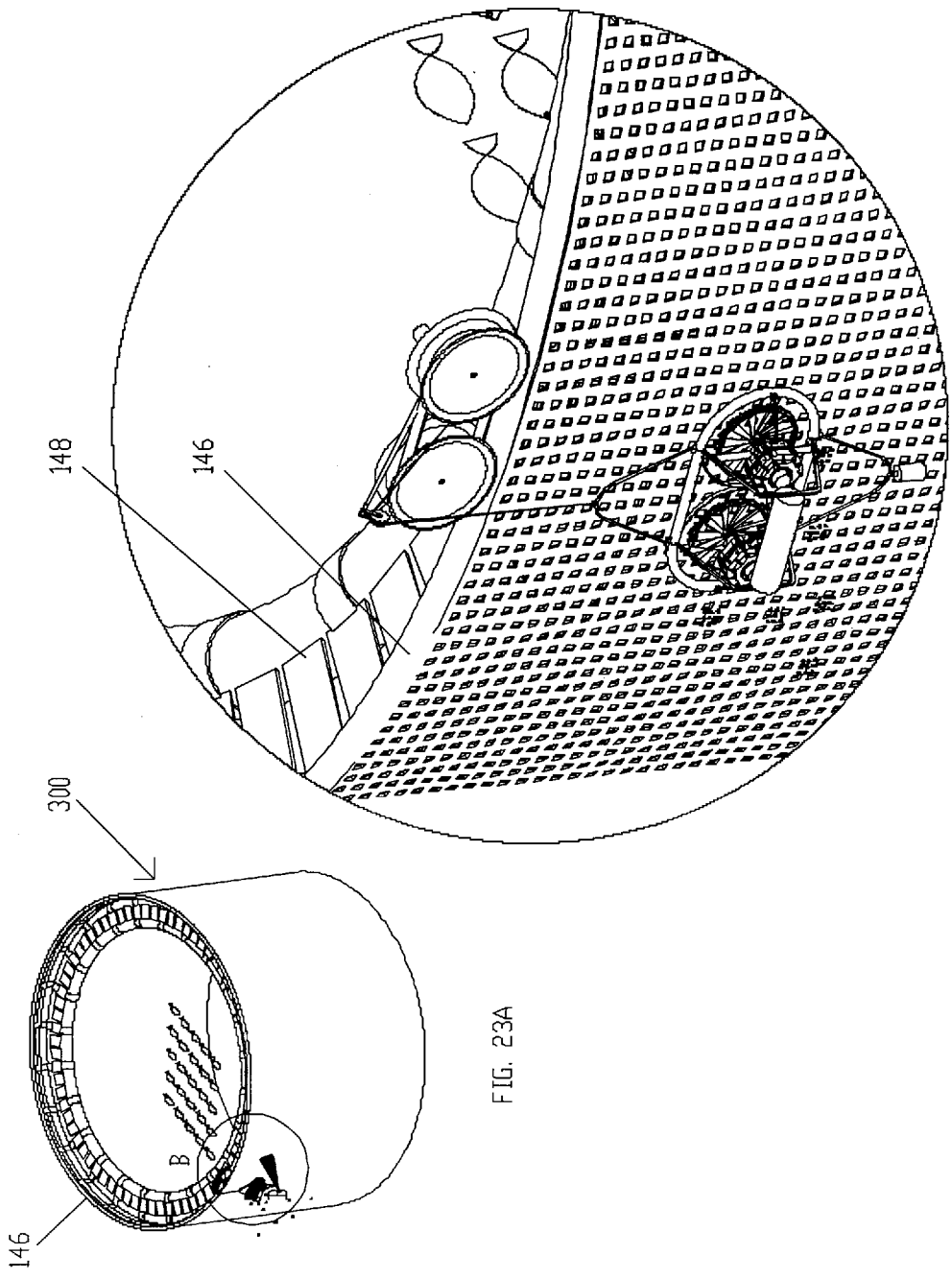



FIG. 23A

FIG. 23B DETAIL B
SCALE 1 : 30