



(11) **EP 3 643 414 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention  
of the grant of the patent:  
**07.06.2023 Bulletin 2023/23**

(51) International Patent Classification (IPC):  
**B08B 3/02** (2006.01) **B08B 9/023** (2006.01)

(21) Application number: **18425080.1**

(52) Cooperative Patent Classification (CPC):  
**B08B 9/023; B08B 3/024; B08B 3/14**

(22) Date of filing: **25.10.2018**

(54) **AN ULTRA-HIGH-PRESSURE WATER JETTING (UHPWJ) HYDRO-BLASTING CLEANING SYSTEM FOR SURFACES**

HYDROSTRAHLREINIGUNGSSYSTEM MIT ULTRAHOCHDRUCKWASSERSTRAHL FÜR OBERFLÄCHEN

SYSTÈME DE NETTOYAGE PAR HYDROSOUFFLAGE DE JET D'EAU À ULTRA-HAUTE PRESSION (UHPWJ) POUR SURFACES

(84) Designated Contracting States:  
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**  
Designated Extension States:  
**BA ME**  
Designated Validation States:  
**KH MA MD TN**

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(43) Date of publication of application:  
**29.04.2020 Bulletin 2020/18**

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## Description

### Field of the invention

[0001] The invention relates to the general field of the Ultra-High-Pressure Water Jetting (UHPWJ) hydro-blasting/cleaning system.

[0002] It relates more particularly to the field of renovation by removal of rust and old coatings, in particular from so-called penstocks. A penstock is an hydraulic pipe consisting of a pipe assembly, intended to convey pressurized water to an hydroelectric plant located downstream and below the water reservoir that feeds it.

[0003] The present invention aims more particularly at improving the existing cleaning systems used for surface preparation before maintenance coating application.

[0004] Although described with reference to an advantageous application of renovation of a penstock, the invention applies to any robot for all types of surfaces of very large dimensions and/or of complex shapes and/or of difficult access and/or with a high elevation, like the pipes or other repair pipes of different sizes and geometries and inclination to be carried out without the need for a scaffolding erection and containment.

### Background of the invention

[0005] A large number of pipes of greater or lesser diameter are widely used nowadays in a broad spectrum of industries. For example, local authorities may use large diameter pipes for stormwater drainage and water management in general.

[0006] The oil and gas industry, as well as the power generation industry, use these pipes for the transportation of oil and gas.

[0007] Hydropower plants use very large diameter pipes, so-called penstocks for the transport of water under pressure.

[0008] Although numerous and varied in their constraints and implementations, all industries using pipes face the same challenges: limited pipe life, high repair costs, major service interruptions, major impact infrastructure, staff security, and the effectiveness of the repair.

[0009] The use of robots for cleaning and/or internal inspection of pipes, various pipes and pipes are already known.

[0010] Applicant companies of the present application have sought to define a robot for adequate surface preparation and coating application during renovation to the outside of penstocks.

[0011] These penstocks usually consist of metal tubes assembled along a slope and protected by exterior and interior coating/lining.

[0012] It is necessary to regularly maintain these penstocks and in particular to renew the external protection by removing the existing outer coating and any oxidations and replacing it with a new one.

[0013] In general, the maintenance or renovation consists in performing a surface preparation complying with the high standard requirements for the application of a new coating of paint. This preparation may for example consist of an abrasive blasting, also commonly referred to as shot blasting, which makes it possible to create a specific surface profile needed for the adhesion and the application of a new coating of paint.

[0014] These operations are currently done manually and are particularly labor intensive, fatiguing, even dangerous.

[0015] Beforehand, they require a long, delicate and painful preparation.

[0016] Indeed, it is generally necessary to implement scaffolding adapted along the entire length of the penstock to be renovated. This scaffolding can reach hundreds of tons of material to be installed and transported.

[0017] In addition, to limit the impact of renovation projects on the environment, mandatory if surface preparation involves removing asbestos, it is mandatory that companies in charge of the renovation to cover the entire work area with an air tight tarpaulin to be placed on a very long stretch up until a few kilometers.

[0018] The difficulty and health concern, even with appropriate precautions and PPE (Personal Protection Equipment), for the operators in charge of the renovation comes from the fact that they are working in a confined space and that they must remove coatings that may contain toxic substances such as asbestos or heavy metals (lead), CMR (Carcinogenic, Mutagenic and Reprotoxic) substances. It may be true for coatings that are provided for replacement, for example because of the solvents used.

[0019] In addition, this work requires to the operator a high degree of attention and precaution, because the equipment and tools used; for example, for Ultra-High Pressure (UHP) water jetting hoses working at about 3000 bar or blasting lances, have a relatively limited area of action and the attention of the operator must be supported.

[0020] As a result, these operations can take a considerable time both for the work and the verifications, especially since the penstocks can be of great length, up to several kilometers, with steep slope and in hard to reach places.

[0021] The applicant therefore wished to automate this maintenance or renovation of the exterior of these pipes and implement a robot that can perform these renovation operations.

[0022] However, the specifications imposed for such a robot is strict and therefore, the mainly because of strong constraints intrinsic to penstocks.

[0023] In particular, as regards the means of displacement, such a robot must meet the following specifications:

- it must move outside a pipe by its own means and supporting substantial loads, especially for the pur-

pose of being self-contained in paint tanks for coating;

- it must be easily adaptable to a range of different pipe diameters;
- it must be able to move forward or backward, up or down, even in very steep or even vertical lines;
- it must be able to self-maintain outside these pipes, that is to say, by its own means, including in very steep pipes, such as vertical pipes;
- its main parameters of displacement (speeds, cycles ...) must be able to be adjusted precisely and remotely by an operator;
- it must be able to pass small internal obstacles, inherent in the pipes that form irregularities on the outer wall of the pipes, such as junction flanges assembling two adjacent pipes;
- it must be able to pass, by its own means, changes of inclination of the pipes, that is to say, bends likely to be present in the penstock, including a radius of curvature of elbows that can be at least equal to 3 times the diameter of the pipe.

**[0024]** The applicants have reached to design and implement a very satisfactory mobile robot, which perfectly answers to the above-mentioned specifications.

**[0025]** In addition to the above drawbacks, the inventors of the present invention have been able to show that the robotic cleaning solutions for pipelines did meet the strict surface preparation standards imposed for cleaning penstocks and repainting requiring state standardized surface according to ISO 8501-1, 8501-2, 8501-4.

**[0026]** Among the robotic cleaning solutions known for cleaning pipes, there may be mentioned those using a brushing, as described in patents US5528789, JP2001096246, or CN10169890.

**[0027]** There are also solutions by projection of a jet of compressed air at high pressure.

**[0028]** Some solutions combine both brushing and air jet projection, as described for example in US6026538.

**[0029]** Finally, we can cite the classic solutions of Ultra High-Pressure Water projection.

**[0030]** All these proposed solutions cannot be effective to carry out efficient dusting and/or to eliminate heavy rust scales and oxides from deep corrosion pits on the surface of the pipes, more particularly those resulting from the corrosion of the metallic ducts forming characteristic blisters and to respect the criteria of application of the aforementioned standards ISO 8501-1, 8501-2, 8501-4.

**[0031]** They then searched among the existing machines and equipment, if some could be adapted on a pipe renovation robot.

**[0032]** More specifically, they sought solutions that could be both very efficient, clean, that is to say that propose a localized fluid projection and recovery of waste and projected fluid, and compact to be easily implemented in a very small environment dedicated in a robot.

**[0033]** Finally, they sought solutions that reduce the

cost of operations, notably due to transportation and handling, especially by helicopter, the various components along penstocks, as renovation progresses.

**[0034]** US2016/0016205 A1 patent application describes a system according to the preamble of main claim 1.

**[0035]** However, none of the known machines has all of these advantages.

**[0036]** Therefore, there is a need to find a cleaning solution for the renovation of the exterior surfaces of pipes, in particular pressure pipes, in particular to meet the high stress of the past, while meeting the safety standards in demanding environments, including with a very difficult access to operators.

**[0037]** More generally, there is a need to find a cleaning solution for surfaces of very large dimensions and/or of complex shapes and/or of difficult access and/or with a high elevation, to eliminate the drawbacks above.

**[0038]** The invention aims to address all or part of these needs.

### Summary of the invention

**[0039]** Thus, the subject of the invention, according to one of its aspects, is an Ultra-High-Pressure Water Jetting (UHPWJ) hydro-blasting/cleaning system for surfaces comprising:

- a mobile robot or a lifting and/or handling equipment, like a cherry picker, adapted to be displaced on or next to the surface to be hydro-blasted/scoured, said mobile robot carrying:
  - a UHP cleaning head with a shell forming a bell adapted to confine the projected water and to capture, at source, the waste hydro-blasted/scoured by the projected water on the surface, said bell having at least one fluidic inlet with a water nozzle to project water inside the bell and at least one fluidic outlet,
  - a suction tank accommodating a cyclone separator adapted to separate the water containing the hydro-blasted/scoured waste from air, the suction tank having at least one fluidic inlet connected at the fluidic outlet of the shell, and at least two fluidic outlets,
- a stationary part comprising:
  - a UHP water feeding pump, connected to the fluidic inlet of the bell, in order to project water inside it,
  - a vacuum suction device, connected to one of the fluidic outlet of the suction tank such, in order to suck the water containing the waste hydro-blasted/scoured inside the bell,
  - a filtering and collecting unit comprising at least one fluidic inlet connected to the other fluidic out-

let of the suction tank, in order to collect the water containing hydro-blasted/scoured waste, said unit comprising at least one filtering device to separate the water from the scoured waste and at least one water tank connected downstream to the filtering device, in order to collect the filtered water.

**[0040]** The mobile robot according to the invention is an autonomous robot, intended to be used in an outdoor environment for the external renovation of surfaces, whose displacement is guaranteed on the surfaces, even for very long lengths and/or for very large inclinations of the surfaces, and where appropriate in very difficult and / or restricted environments.

**[0041]** By "autonomous robot" is meant here the usual meaning of technology, namely an equipment whose mobile device is robotized, that is to say constitutes a mechatronic device, to enable it to move autonomously and perform a work operation on a surface automatically, i.e. without human intervention.

**[0042]** Thus, the invention mainly consists of a UHPWJ system with a rotating cleaning head which can be kept in contact with the surface to be hydro-blasted/cleaned and with sucking means which are judiciously physically separated, i.e. a cyclone type device which is mounted on the mobile robot and therefore can separate the gas phase from the liquid and solid phases, very near to the hydro-blasting/cleaning head, while minimizing the flow pressure drop, and a vacuum suction device that is placed up to a significant distance from the cleaning head and generates the depression that drives the three-phase mixture into the cyclone.

**[0043]** The solution according to the invention has the following main advantages:

- a closed loop,
- a high degree of automatization hydro-blasting/cleaning surface for pipes, penstocks and other surfaces, which allows a reduced intervention time on site,
- a reduced displacement for the system components along the working surface, because of the on-board cyclone can be connected to the vacuum device on the floor over long lengths (up to 50 m) and be emptied periodically by gravity,
- negligible particle emission and operator intervention, allowing for safe operation even in case of removal of coating containing dangerous components (i.e. asbestos, lead, CMR) and/or in places with limited access possibilities,
- a minimum safety risk related to working in challenging environment, such as steep slope, because of the control of the whole operation of the UHPWJ system through an electronic command console by an operator safely, standing on the ground on the side of the penstock,
- and an easy disassembled and reassembled UHP-

WJ, allowing for transportation with standard size helicopters.

#### Brief description of the drawings

**[0044]** The invention will be able to be better understood on reading the following description of exemplary and nonlimiting implementations thereof, and on studying the appended figures in which:

- Figure 1 is a schematic perspective view of the arrangement of the main parts of an example of the UHPWJ system according to the invention;
- Figure 2 is a schematic perspective view of the mobile apparatus of an example autonomous robot according to the invention, which is in an installed configuration hooked onto a penstock to be renovated;
- Figure 3 is another schematic perspective view of the mobile device according to Figure 2;
- Figure 4A and 4B are front views showing the transition across a support saddle of the penstock by the mobile robot according to the invention;
- Figure 5 is a detailed front view of the cleaning head of the UHPWJ system according to the invention, mounted on its rack for its displacement around the penstock;
- Figure 6 is a perspective view of the cleaning head of the UHPWJ system according to the invention;
- Figure 7 is a perspective view of the suction tank and its inclination means of the UHPWJ system according to the invention, on-board on the robot frame;
- Figures 8 and 9 are respectively a perspective view and a cross-section longitudinal view of the suction tank alone;
- Figure 10 is a schematic perspective view of the filtering and collecting unit of the UHPWJ system according to the invention.

#### Detailed description

**[0045]** For clarity purposes, the same references designating the same elements of a UHPWJ system according to the invention are used for all the Figures 1 to 9.

**[0046]** It is specified that the terms "front" and "rear" refer to a direction of movement of a robot according to the invention on the outer surface of a penstock. In the illustrated example, the movement of the robot is reversible: also, it goes without saying that part of the robot, designated before, in a direction of movement of the robot in the pipe becomes a rear portion in the opposite direction of movement.

**[0047]** The terms "upstream" and "downstream" are to be understood by reference to the location of the mobile robot on the penstock to be renovated.

**[0048]** Figure 1 shows the main components of a UHPWJ hydro-blasting/cleaning system, globally designated by numeral reference 1, which is configured in a closed loop for the renovation of a penstock (P).

**[0049]** The UHPWJ hydro-blasting/cleaning system 1 comprises a mobile robot 2 which is adapted to displace by itself on the exterior surface of the penstock P and a stationary part 3 in a fluidic connection with the robot.

**[0050]** The mobile robot 2 carries a cleaning head 4 and a suction tank 5 connected to the cleaning head 4.

**[0051]** The cleaning head 4 is shaped with a shell 40 forming a bell adapted to confine the projected water and to capture, at source, the waste hydro-blasted/scoured by the projected water on the surface.

**[0052]** The suction tank 5 accommodates a cyclone separator which makes it possible to extract the waste from the re-sucked water from the pickling shell 40 of the cleaning head 4. In other words, the cyclone separator 5 is adapted to separate the water containing the hydro-blasted/scoured waste from air. The waste is mainly the coating/rust removed from the penstock. The fact that the cyclone 5 is mounted on the frame of the robot 2 allows the separation the phases very near to the hydro-blasting/cleaning head 4, and hence minimizes the flow pressure drop.

**[0053]** The stationary part 3 comprises firstly a UHP water feeding pump, not shown connected to the fluidic inlet of the bell of the head 4, in order to project water inside it. The high-pressure water pump can be located at a very long distance from the mobile robot (as far as 1.500 [m]), connected to it by special steel reinforced hoses. A buffer water tank, for the filtered recirculated water which feeds the pump, can be also foreseen.

**[0054]** A vacuum pump 6 is connected to the suction tank 5 through a fluidic line 60 in order to generate the depression that drives the three-phase mixture into the cyclone 5, separating the gas phase from the liquid and solid phase, i.e. sucking the water containing the waste hydro-blasted/scoured inside the bell of the cleaning head 4. The vacuum pump 6 may be placed at a high distance from the cleaning head 4. Typically, the distance can be up to 50 [m], allowing to work on a 100 [m] stretch of pipe without the need to displace it.

**[0055]** The vacuum suction pump 6, is placed on the ground, comprises preferably two filters, the upstream one being a pocket filter whereas the downstream one being a mesh filter.

**[0056]** At last, a filtering and collecting unit 7 connected to the suction tank 5 through a fluidic line 70 is provided. The unit 7 is configured to collect the water containing hydro-blasted/scoured waste.

**[0057]** The unit 7 mainly comprises a plural filtering device 8 to separate the water to be recycled from the hydro-blasted/scoured waste and at least one water tank 9 connected downstream to the filtering device, in order to collect the filtered water.

**[0058]** A water buffer tank 10 can be provided between the suction tank 5 and the filtering and collecting unit 7.

**[0059]** The unit 7 can be located at a very high distance from the mobile robot 2, typically up to 1-1,5 [km].

**[0060]** All the components of the UHPWJ system are electrically powered. Alternatively, a diesel power feed-

ing can be foreseen.

**[0061]** Figures 2 and 3 show the mobile part of an autonomous robot according to the invention for stripping by water cleaning the outer surface of a penstock.

**[0062]** The mobile robot 2 embeds the whole work tools and fluids required for the renovation of a penstock.

**[0063]** More specifically, the working tools are carried by a detailed tool holder thereafter and the fluids (water, vacuum suction) feed the robot from a fixed platform in an area near the penstock to be renovated, as detailed below.

**[0064]** The mobile robot 2 firstly comprises a frame 20 which extends along an axis longitudinally (X), as well as a plurality of steering wheel trains 21.

**[0065]** As can be seen in figs. 2 and 3, these steering wheels 21 will enable the apparatus to roll on the outer surface of the penstock (P) during a renovation operation thereof. The operation of the wheel sets will be explained in more detail below.

**[0066]** To ensure the maintenance of the mobile device 2 on the penstock, means 22 attached to the frame 20 are provided. These means 22 are made in the form of clamps which hook the frame 20 around the outer surface of the pipe (P). The operation of these clamps will also be explained in more detail below.

**[0067]** These means 22 comprise four independent extension arms 23 attached to the frame 20, which extend laterally outward two by two on both sides of the latter. These four independently activated arms 23 are intended for obstacle avoidance and stability purposes. The distance separating the free end of two extension arms 23 on either side of the frame is greater than the diameter of the penstock (P).

**[0068]** On each extension arm 23, a plating arm 24 is pivotally mounted about an axis substantially parallel to the axis of the frame. Each plating arm 24 supports a support wheel 25.

**[0069]** An electro-pneumatic cylinder 26 is mounted between an extension arm 23 and a plating arm 24.

**[0070]** Thus, when one actuates in one direction a cylinder 26, the rod 260 thereof moving from a retracted position to an extended position, which causes pivoting of the plating arm 24 and the support wheel 25.

**[0071]** In the deployed position of the cylinder rods 260, the support wheels 25 are all pressed against the forced outer surface and thus generate frame holding forces towards the inside of the pipe.

**[0072]** Here, the frame 20 is hooked on the penstock (P).

**[0073]** The support wheels 25 and associated plating arms 24 are raised by activating the cylinders 26 in the opposite direction, that is to say, by retracting the cylinder rods 260.

**[0074]** For example, the lifting of the plating arms 24 with their support wheels 25 may be realized, when during the displacement of the mobile robot 2 on the penstock P, they encounter junction flanges J between adjacent portions of the penstock P and which delimit a

diameter greater than the outside diameter of the pipe which constitutes the rolling surface of the mobile robot 2.

**[0075]** In order to allow the autonomous movement of the robot along a penstock to be renovated, a cable hoisting system 27, with a removable anchoring device not shown and motorized winches 28 and cable drums 29 embedded on the mobile device is planned.

**[0076]** At one end of the longitudinal front end of the frame 20, is fixed a ring 40 whose inner diameter is greater than the outside diameter of the penstock P.

**[0077]** A tool carriage 41 may be a rack slidably mounted over the entire periphery of the ring 40. The ring 40 may for example be shaped into a rack on which a wheel moving the carriage 41 can come into mesh by means of a motorization adapted. This carriage 41 serves as support for at least the cleaning head 4 for renovating the penstock.

**[0078]** The ring 40 and the circular rack 41 can be opened for the passage of the support saddles (S) of the penstock (P).

**[0079]** A closed configuration of the ring 40 is shown on Figure 4A while an open configuration of the ring 40 is shown on Figure 4B: the actuation of two electro-pneumatic cylinders 42 can discard moving portions 43 from the portions 44 fixed to the frame 20 of the robot 2.

**[0080]** Thus, the cylinders 42 allow for obstacle avoidance and ensure good contact between the cleaning head 4 and the surface to be hydro-blasted/cleaned.

**[0081]** In operation, certain safety conditions may be imposed:

- the ring 40 can only be opened if the cleaning head 4 is positioned on the fixed portions 44 of the ring;
- the displacement of the cleaning head 4 outside the fixed ring portions 44 may be permitted if the movable portions 43 are closed and joined with each other.

**[0082]** The circular rack 41 allows the circular displacement of the cleaning head around the ring 40.

**[0083]** More precisely, as shown on Figures 6 and 7, the cleaning head 4 is mounted on a plate 45 which can slide on tracks 46.

**[0084]** The displacement of the cleaning head 4 on these tracks 46 can be achieved by means of two pneumatic cylinders 47. The deployed position of the cylinders 47 presses the bell 400 of the cleaning head 4 on the surface of the penstock P. Conversely, the folded position of the cylinders 47 disengages the bell from this surface.

**[0085]** These cylinders 47 ensures that the bell 400 of the cleaning head 4 is kept in good contact with the surface of the penstock (P) sealing within the head 4 the UHPWJ flow, and the consequently produced particle and droplets.

**[0086]** The tracks support 48 is a mobile carriage with rollers 480 bearing against the ring 40, which can move over the entire periphery of the ring.

**[0087]** A motor 49, of the brushless type, attached to the carriage 48 allows through its output gear meshing

on the rack 46 to accurately position the cleaning head 4 at any angular position on the ring.

**[0088]** Depending on the presence of cables and/or hydraulic hoses in the vicinity of the cleaning head 4 and the ring 40, the displacement of the head may be limited to predetermined angular portions.

**[0089]** The cleaning head 4 comprises a jetting water nozzle (not shown) which is capable of projecting water at a ultra-high pressure, typically between 2000 and 3000 bars. This nozzle is accommodated inside the bell 400 of the head 4.

**[0090]** The water nozzle can be feed with pressurized water by an inlet duct 401 passing through the bell 400.

**[0091]** Besides, the head shell 400 and the sealing top of the cleaning head 4 is purposely-designed in order to locate two vacuum suction ducts 402. These two ducts are arranged diametrically opposite to each other on a diameter circular shape of the bell 400.

**[0092]** This arrangement is particularly advantageous because the depression inside the bell 400 is better applied than with only one suction duct and thus, no amount of liquid or solid particle are emitted in the atmosphere, i.e. the sucking is perfectly ensured. This ensures very low environmental impact and minimizing the safety hazard thanks to the vacuum conditions, which ensure an effective seal between the head 4 and the hydro-blasted surface of the penstock (P).

**[0093]** Moreover, the compact design of the cleaning head and of its associated slide device allows to hydro-blast/clean the pipes with small clearance between the bottom part of the pipe (penstock) and the ground below or lateral constraints such as rocks.

**[0094]** Figure 7 shows an advantageous mounting of the suction tank 5 accommodating the cyclone separator, on the frame 20 of the robot 2.

**[0095]** The cyclone tank 5 is mounted with articulation on a dedicated support 50. This support is equipped with an inclinometer (not shown).

**[0096]** In function of the inclination of the suction tank 5, measured by the inclinometer 50, the tank 5 is modified by at least one pneumatically activated jack 51 to ensure the vertical positioning of the cyclone separator whatever the inclination of the surface to be hydro-blasted/cleaned.

**[0097]** The cyclone 5 is shown alone on Figure 8.

**[0098]** The tank 5 includes mainly a lateral cylindrical shell 52 whose top part is closed with a curved lid 53 and the bottom part is shaped as a frustum-conical shape 54.

**[0099]** A first duct 55 integral with the lid 53 is connected to the cleaning head 4 while a second duct 56 also integral with the lid 53 is connected to the suction pump 6.

**[0100]** A third duct 57 integral with the inferior end of the frustum-conical shape 54 is connected to the filtering unit 7.

**[0101]** The tank 5 is equipped with a level gauge 58. Once the gauge 58 detects the cyclone tank 5 is filled, thus the system is configured to open automatically a drain valve 59 that discharges the cyclone, channelling the water to the hose 57, that goes to the filtering unit 7.

**[0102]** The filtering unit 7 can be located downstream at a long distance from the frame 20, for example up to 1-1,5 [km]. This filtering unit is configured to separate the solid fraction from the water to be sent to the collecting unit 8 and to be recycled.

**[0103]** Figure 10 shows an advantageous embodiment of the filtering unit 7 whose components are all arranged in a closed space 70, such as a container.

**[0104]** To ensure the recovering of the water containing the solid portion can flow from the cyclone separator, only by gravity, the filtering unit is arranged at an elevation lower than the one of the cyclone separator 5.

**[0105]** The container 70 can be ventilated with exterior atmosphere by a fan 71.

**[0106]** The filtering unit 7 comprising two filtering devices 72, 73, 74 the upstream one 72 being adapted to make the decantation and despoiling of the water containing the collected waste, whereas the downstream one 73 being a first mesh filtering unit and the one 74 being an ultra-fine (1 [μm]) mesh filter.

**[0107]** At the end of the project the filtered water is finally collected in one or more tanks 8, located on site.

**[0108]** After laboratory tests, if the composition is within the range prescribed by the local regulations and law, the filtered and collected water can be then evacuated in an existing drainage pipe, such as the renovated penstock (P).

**[0109]** All the described parts of the UHPWJ system 1 are detachable so as no single piece weighs more than 800 kg and thus they can easily be disassembled and reassembled, allowing for transportation with standard size helicopters.

**[0110]** The whole operation of UHPWJ system 1 can be controlled through electronic command console by an operator safely standing on the ground on the side of the penstock minimizing the safety risk related to working in challenging environment, such as steep slope.

**[0111]** Other variants and enhancements can be provided without in any way departing from the framework of the invention defined by the claims.

**[0112]** Thus, in all the shown embodiments, the mobile robot is specially designed to move around and along a pipe, notably a penstock. But, other mobile robots, are also possible like for example on wheels or on telescopic booms.

**[0113]** The expression "comprising a" should be understood to be synonymous with "comprising at least one", unless otherwise specified.

## Claims

1. A Ultra-High Pressure Water Jetting (UHPWJ) hydro-blasting/cleaning system (1) for surfaces (P), comprising:

- a mobile robot (2) or a lifting and/or handling equipment, like a cherry picker, adapted to be

displaced on or next to the surface to be hydro-blasted/scoured, said mobile robot carrying a cleaning head (4) with a shell (400) forming a bell adapted to confine the projected water and to capture, at source, the waste hydro-blasted/scoured by the projected water on the surface, said bell having at least one fluidic inlet with a water nozzle to project water inside the bell and at least one fluidic outlet,

- a suction tank (5) accommodating a cyclone separator adapted to separate the water containing the hydro-blasted/scoured waste from air, the suction tank having at least one fluidic inlet connected at the fluidic outlet of the shell, and at least two fluidic outlets,
- a stationary part (3) comprising:

- a UHP water feeding pump, connected to the fluidic inlet of the bell, in order to project water inside it,
- a vacuum suction device (6), connected to one of the fluidic outlet of the suction tank such, in order to suck the water containing the waste hydro-blasted/scoured inside the bell,
- a filtering (7) and collecting (8) unit comprising at least one fluidic inlet connected to the other fluidic outlet of the suction tank, in order to collect the water containing hydro-blasted/scoured waste, said unit comprising at least one filtering device to separate the water from the hydro-blasted/scoured waste and at least one water tank connected downstream to the filtering device, in order to collect the filtered water,

characterised in that said mobile robot (2) carries said suction tank (5).

2. A UHPWJ hydro-blasting/cleaning system (1) according to Claim 1, the mobile robot or the lifting and/or handling equipment comprising:

- a frame (20);
- a tool holder rack (41) mounted on a part secured to the frame, and on which the UHP cleaning head is carried.

3. A UHPWJ hydro-blasting/cleaning system (1) according to Claim 2, the UHP cleaning head (4) being mounted with translation capability on the rack (41) between an inactive position in which the cleaning head is far from the surface to be hydro-blasted/scoured and an active position in which the head is pressurized and sealed to the surface to be hydro-blasted/cleaned.

4. A UHPWJ hydro-blasting/cleaning system (1) ac-

cording to Claim 3, the mobile robot (2) or the lifting and/or handling equipment comprising at least one pneumatic jack (47) to move the cleaning head (4) between its active position to its inactive position and vice versa.

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5. A UHPWJ hydro-blasting/cleaning system (1) according to Claims 2 to 4, intended to hydro-blast/clean a pipe (P), notably a penstock, as a surface, the frame (20) of the mobile robot (2) being designed for translation on the pipe by a driving control unit.
6. A UHPWJ hydro-blasting/cleaning system (1) according to Claim 5, the mobile robot (2) comprising a ring (40) fixed at the end of one of the longitudinal ends of the frame (2) and whose inner diameter is greater than the outside of the pipe (P) the tool holder rack (41) being mounted with translation capability over the entire periphery of the ring (40).
7. A UHPWJ hydro-blasting/cleaning system (1) according to any preceding claims, wherein the shell (400) and the sealing top of the cleaning head is purposely-designed in order to locate two vacuum suction ducts (402).
8. A UHPWJ hydro-blasting/cleaning system (1) according to any preceding claims, the mobile robot (2) comprising a support (50) for the suction tank (5) which is levelled by an inclinometer, the suction tank (5) being mounted with articulation on the support such that in function the inclination of the suction tank, measured by the inclinometer is modified by at least one pneumatically activated jack (51) to ensure the vertical positioning of the cyclone separator whatever the inclination of the surface to be hydro-blasted/cleaned.
9. A UHPWJ hydro-blasting/cleaning system (1) according to any preceding claims, the vacuum suction device (6) comprising at least one filter (72, 73, 74) adapted to filter the sucked air separated inside the cyclone separator before its discharge to the atmosphere.
10. A UHPWJ hydro-blasting/cleaning system (1) according to Claim 9, the vacuum suction comprising three filters (72, 73, 74), the upstream one (72) being a filter press whereas the downstream ones (73, 74) being mesh filters.
11. A UHPWJ hydro-blasting/cleaning system (1) according to any preceding claims, the filtering and collecting unit (7, 8) being arranged at an altitude level which is lower than the one of the cyclone separator (5) such that the water containing the solid portion of the waste can be evacuated from the separator

and collected by the filtering and collecting unit (7,8), by gravity.

12. A UHPWJ hydro-blasting/cleaning system (1) according to any preceding claims, the filtering and collecting unit (7, 8) comprising three filtering devices, the upstream (72) being adapted to make the decantation and despoiling of the water containing the collected waste whereas the downstream ones (73, 74) being mesh filters.
13. A UHPWJ hydro-blasting/cleaning system (1) according to any preceding claims, comprising an electronic command console which can be controlled by an operator for the whole operations of the system.
14. A UHPWJ hydro-blasting/cleaning system (1) according to any preceding claims, the water tank being connected to an existing draining pipe (P).

#### Patentansprüche

1. Ultrahochdruck-Wasserstrahl (*Ultra-High Pressure Water Jetting* - UHPWJ)-Hydroblasting/Reinigungssystem (1) für Oberflächen (P), umfassend:
  - einen mobilen Roboter (2) oder eine Hebe- und/oder Handhabungsausrüstung, wie z. B. eine Hubarbeitsbühne, dazu angepasst, auf oder neben der mit Hydroblasting/Abtragen zu bearbeitenden Oberfläche versetzt werden zu können, wobei der mobile Roboter einen Reinigungskopf (4) mit einem Gehäuse (400) trägt, welches eine Glocke ausbildet, die dazu angepasst ist, das gespritzte Wasser einzudämmen und an der Quelle die durch das auf die Oberfläche gespritzte Wasser mit Hydroblasting/Abtragen entfernten Abfälle aufzufangen, wobei die Glocke mindestens einen Fluideinlass mit einer Wasserdüse zum Spritzen von Wasser in die Glocke und mindestens einen Fluidauslass aufweist,
  - einen Saugtank (5), der einen Zyklonabscheider aufnimmt, dazu angepasst, das Wasser, das den durch Hydroblasting/Abtragen entfernten Abfall enthält, von der Luft zu trennen, wobei der Saugtank mindestens einen Fluideinlass, der mit dem Fluidauslass des Gehäuses verbunden ist, und mindestens zwei Fluidauslässe aufweist,
  - einen stationären Teil (3), umfassend:
    - \* eine UHP-Wasserspeisepumpe, die mit dem Fluideinlass der Glocke verbunden ist, um Wasser in diese zu spritzen,
    - \* eine Unterdrucksaugvorrichtung (6), die mit einem der Fluidauslässe des Saugbe-



- hälters verbunden ist, um das Wasser, das die durch Hydroblasting/Abtragen entfernten Abfälle enthält, in die Glocke zu saugen, \* eine Filter- (7) und Sammeleinheit (8), mindestens einen Fluideinlass umfassend, der mit dem anderen Fluidauslass des Saugtanks verbunden ist, um das Wasser zu sammeln, das durch Hydroblasting/Abtragen entfernten Abfälle enthält, wobei die Einheit Folgendes umfasst: mindestens eine Filtervorrichtung zum Abscheiden des Wassers von dem durch Hydroblasting/Abtragen entfernten Abfall und mindestens einen Wassertank, der stromabwärts der Filtervorrichtung angeschlossen ist, um das gefilterte Wasser zu sammeln, **dadurch gekennzeichnet, dass** der mobile Roboter (2) den Saugtank (5) trägt.
2. UHPWJ-Hydroblasting/Reinigungssystem (1) nach Anspruch 1, wobei der mobile Roboter oder die Hebe- und/oder Handhabungsausrüstung Folgendes umfasst:
    - einen Rahmen (20);
    - ein Werkzeughaltergestell (41), das an einem am Rahmen befestigten Teil befestigt ist und auf der der UHP-Reinigungskopf getragen wird.
  3. UHPWJ-Hydroblasting/Reinigungssystem (1) nach Anspruch 2, wobei der UHP-Reinigungskopf (4) auf dem Gestell (41) derart angebracht ist, dass er bewegbar ist zwischen einer inaktiven Position, in der der Reinigungskopf weit von der durch Hydroblasting/Abtragen zu reinigenden Oberfläche entfernt ist, und einer aktiven Position, in der der Kopf mit Druck beaufschlagt und zu der durch Hydroblasting/Reinigen zu behandelnden Oberfläche hin abgedichtet wird.
  4. UHPWJ-Hydroblasting/Reinigungssystem (1) nach Anspruch 3, wobei der mobile Roboter (2) oder die Hebe- und/oder Handhabungsausrüstung mindestens einen pneumatischen Heber (47) zum Bewegen des Reinigungskopfes (4) zwischen seiner aktiven Position in seiner inaktiven Position und umgekehrt umfasst.
  5. UHPWJ-Hydroblasting/Reinigungssystem (1) nach den Ansprüchen 2 bis 4, vorgesehen für Hydroblasting/Reinigen eines Rohrs (P), insbesondere einer Druckrohrleitung, als eine Oberfläche, wobei der Rahmen (20) des mobilen Roboters (2) für ein Verschieben in dem Rohr durch eine Antriebssteuereinheit ausgelegt ist.
  6. UHPWJ-Hydroblasting/Reinigungssystem (1) nach Anspruch 5, wobei der mobile Roboter (2) einen Ring (40) umfasst, der am Ende eines der Längsenden des Rahmens (2) befestigt ist und dessen Innendurchmesser größer ist als die Außenseite des Rohrs (P), wobei das Werkzeughaltergestell (41) über den gesamten Umfang des Rings (40) verschiebbar angebracht ist.
  7. UHPWJ-Hydroblasting/Reinigungssystem (1) nach einem der vorhergehenden Ansprüche, wobei das Gehäuse (400) und die Dichtungsoberseite des Reinigungskopfs absichtlich so gestaltet sind, dass sie zwei Vakuumsaugkanäle (402) anordnen.
  8. UHPWJ-Hydroblasting/Reinigungssystem (1) nach einem der vorhergehenden Ansprüche, wobei der mobile Roboter (2) eine Halterung (50) für den Saugtank (5) umfasst, die durch einen Neigungsmesser nivelliert wird, wobei der Saugtank (5) gelenkig auf dem Träger montiert ist, sodass im Betrieb die vom Neigungsmesser gemessene Neigung des Saugtanks durch mindestens einen pneumatisch aktivierten Heber (51) modifiziert wird, um die vertikale Positionierung des Zyklonabscheiders bei jeder Neigung der zu durch Hydroblasting/Reinigung zu bearbeitenden Oberfläche zu gewährleisten.
  9. UHPWJ-Hydroblasting/Reinigungssystem (1) nach einem der vorhergehenden Ansprüche, wobei die Unterdrucksaugvorrichtung (6) mindestens einen Filter (72, 73, 74) umfasst, angepasst zum Filtern der zuvor innerhalb des Zyklonabscheiders abgeschiedenen angesaugten Luft, bevor diese an die Atmosphäre abgegeben wird.
  10. UHPWJ-Hydroblasting/Reinigungssystem (1) nach Anspruch 9, wobei das Unterdruckabsaugen drei Filter (72, 73, 74) umfasst, wobei der stromaufwärtige (72) eine Filterpresse ist, während die stromabwärtigen (73, 74) Maschenfilter sind.
  11. UHPWJ-Hydroblasting/Reinigungssystem (1) nach einem der vorhergehenden Ansprüche, wobei die Filter- und Sammeleinheit (7, 8) auf einem Höhenniveau angeordnet ist, das niedriger als das des Zyklonabscheiders (5) ist, sodass das Wasser, das den Feststoffanteil des Abfalls enthält, aus dem Abscheider entfernt werden und durch die Filter- und Sammeleinheit (7, 8) durch Schwerkraft gesammelt werden kann.
  12. UHPWJ-Hydroblasting/Reinigungssystem (1) nach einem der vorhergehenden Ansprüche, wobei die Filter- und Sammeleinheit (7, 8) drei Filtervorrichtungen umfasst, wobei die stromaufwärtige (72) dazu angepasst ist, um das Abgießen und Reinigen des Wassers durchzuführen das den gesammelten Abfall enthalten, während die stromabwärtigen (73, 74) Maschenfilter sind.

13. UHPWJ-Hydroblasting/Reinigungssystem (1) nach einem der vorhergehenden Ansprüche, umfassend eine elektronische Befehlskonsole, die zum gesamten Betrieb des Systems von einem Bediener gesteuert werden kann.
14. UHPWJ-Hydroblasting/Reinigungssystem (1) nach einem der vorangehenden Ansprüche, wobei der Wassertank mit einem bestehenden Ablassrohr (P) verbunden ist.

## Revendications

1. Système de nettoyage/hydrosoufflage de jet d'eau à ultra haute pression (UHPWJ) (1) pour des surfaces (P), comprenant :

un robot mobile (2) ou un équipement de levage et/ou de manipulation, tel qu'une nacelle élévatrice, conçu pour être déplacé sur ou à côté de la surface à hydrosouffler/décaper, ledit robot mobile transportant une tête de nettoyage (4) ayant une coque (400) formant une cloche conçue pour confiner l'eau projetée et pour capturer, à la source, les déchets hydrosoufflés/décapés par l'eau projetée sur la surface, ladite cloche ayant au moins une entrée de fluide dotée d'un gicleur pour projeter l'eau à l'intérieur de la cloche et au moins une sortie de fluide,

un réservoir d'aspiration (5) logeant un cyclone de séparation conçu pour séparer l'eau contenant les déchets hydrosoufflés/décapés de l'air, le réservoir d'aspiration ayant au moins une entrée de fluide reliée à la sortie de fluide de la coque, et au moins deux sorties de fluide,

une partie fixe (3) comprenant :

une pompe d'alimentation en eau UHP, reliée à l'entrée de fluide de la cloche, afin de projeter l'eau à l'intérieur de celle-ci,

un dispositif d'aspiration sous vide (6), relié à l'une des sorties de fluide du réservoir d'aspiration, afin d'aspirer l'eau contenant les déchets hydrosoufflés/décapés à l'intérieur de la cloche,

une unité de filtration (7) et de collecte (8) comprenant au moins une entrée de fluide reliée à l'autre sortie de fluide du réservoir d'aspiration, afin de collecter l'eau contenant les déchets hydrosoufflés/décapés, ladite unité comprenant au moins un dispositif de filtration pour séparer l'eau des déchets hydrosoufflés/décapés et au moins un réservoir d'eau relié en aval au dispositif de filtration, afin de collecter l'eau filtrée,

**caractérisé en ce que** ledit robot mobile (2) transporte ledit réservoir d'aspiration (5).

2. Système de nettoyage/hydrosoufflage UHPWJ (1) selon la revendication 1, le robot mobile ou l'équipement de levage et/ou de manipulation comprenant :

5 un châssis (20) ;  
une crémaillère de support d'outil (41) montée sur une partie fixée au châssis, et sur laquelle la tête de nettoyage UHP est transportée.

- 10 3. Système de nettoyage/hydrosoufflage UHPWJ (1) selon la revendication 2, la tête de nettoyage UHP (4) étant montée avec une capacité de translation sur la crémaillère (41) entre une position inactive dans laquelle la tête de nettoyage est éloignée de la surface à hydrosouffler/décaper et une position active dans laquelle la tête est mise sous pression et scellée à la surface pour être hydrosoufflée/nettoyée.

- 20 4. Système de nettoyage/hydrosoufflage UHPWJ (1) selon la revendication 3, le robot mobile (2) ou l'équipement de levage et/ou de manipulation comprenant au moins un vérin pneumatique (47) pour déplacer la tête de nettoyage (4) entre sa position active et sa position inactive et vice-versa.

- 25 5. Système de nettoyage/hydrosoufflage UHPWJ (1) selon les revendications 2 à 4, destiné à hydrosouffler/nettoyer un tuyau (P), notamment une conduite forcée, en tant que surface, le châssis (20) du robot mobile (2) étant conçu pour une translation sur le tuyau par une unité de commande d'entraînement.

- 30 6. Système de nettoyage/hydrosoufflage UHPWJ (1) selon la revendication 5, le robot mobile (2) comprenant une bague (40) fixée à l'extrémité de l'une des extrémités longitudinales du châssis (2) et dont le diamètre interne est supérieur à l'extérieur du tuyau (P), la crémaillère de support d'outil (41) étant montée avec une capacité de translation sur toute la périphérie de la bague (40).

- 35 7. Système de nettoyage/hydrosoufflage UHPWJ (1) selon l'une quelconque des revendications précédentes, dans lequel la coque (400) et le sommet de scellement de la tête de nettoyage sont conçus dans le but de loger deux conduits d'aspiration sous vide (402).

- 40 8. Système de nettoyage/hydrosoufflage UHPWJ (1) selon l'une quelconque des revendications précédentes, le robot mobile (2) comprenant un support (50) pour le réservoir d'aspiration (5) qui est nivelé par un inclinomètre, le réservoir d'aspiration (5) étant monté avec une articulation sur le support de sorte que en fonction, l'inclinaison du réservoir d'aspiration, mesurée par l'inclinomètre, est modifiée par au moins un vérin pneumatique (51) pour assurer le po-

sitionnement vertical du cyclone de séparation quel-  
le que soit l'inclinaison de la surface à hydrosouf-  
fler/nettoyer.

9. Système de nettoyage/hydrosoufflage UHPWJ (1) 5  
selon l'une quelconque des revendications précé-  
dentes, le dispositif d'aspiration sous vide (6) com-  
prenant au moins un filtre (72, 73, 74) conçu pour  
filtrer l'air aspiré séparé à l'intérieur du cyclone de  
séparation avant son évacuation dans l'atmosphère. 10
10. Système de nettoyage/hydrosoufflage UHPWJ (1)  
selon la revendication 9, l'aspiration sous vide com-  
prenant trois filtres (72, 73, 74), le filtre amont (72)  
étant un filtre presse tandis que les filtres aval (73,  
74) sont des filtres à tamis. 15
11. Système de nettoyage/hydrosoufflage UHPWJ (1)  
selon l'une quelconque des revendications précé-  
dentes, l'unité de filtration et de collecte (7, 8) étant 20  
disposée à un niveau d'altitude qui est inférieur à  
celui du cyclone de séparation (5) de sorte que l'eau  
contenant la partie solide des déchets peut être éva-  
cuée du séparateur et collectée par l'unité de filtra-  
tion et de collecte (7, 8) par la gravité. 25
12. Système de nettoyage/hydrosoufflage UHPWJ (1)  
selon l'une quelconque des revendications précé-  
dentes, l'unité de filtration et de collecte (7, 8) com-  
prenant trois dispositifs de filtration, le dispositif 30  
amont (72) étant conçu pour réaliser la décantation  
et le nettoyage de l'eau contenant les déchets col-  
lectés tandis que les dispositifs aval (73, 74) sont  
des filtres à tamis. 35
13. Système de nettoyage/hydrosoufflage UHPWJ (1)  
selon l'une quelconque des revendications précé-  
dentes, comprenant une console de commande  
électronique qui peut être commandée par un opé-  
rateur pour l'ensemble des opérations du système. 40
14. Système de nettoyage/hydrosoufflage UHPWJ (1)  
selon l'une quelconque des revendications précé-  
dentes, le réservoir d'eau étant relié à un tuyau de  
vidange existant (P). 45

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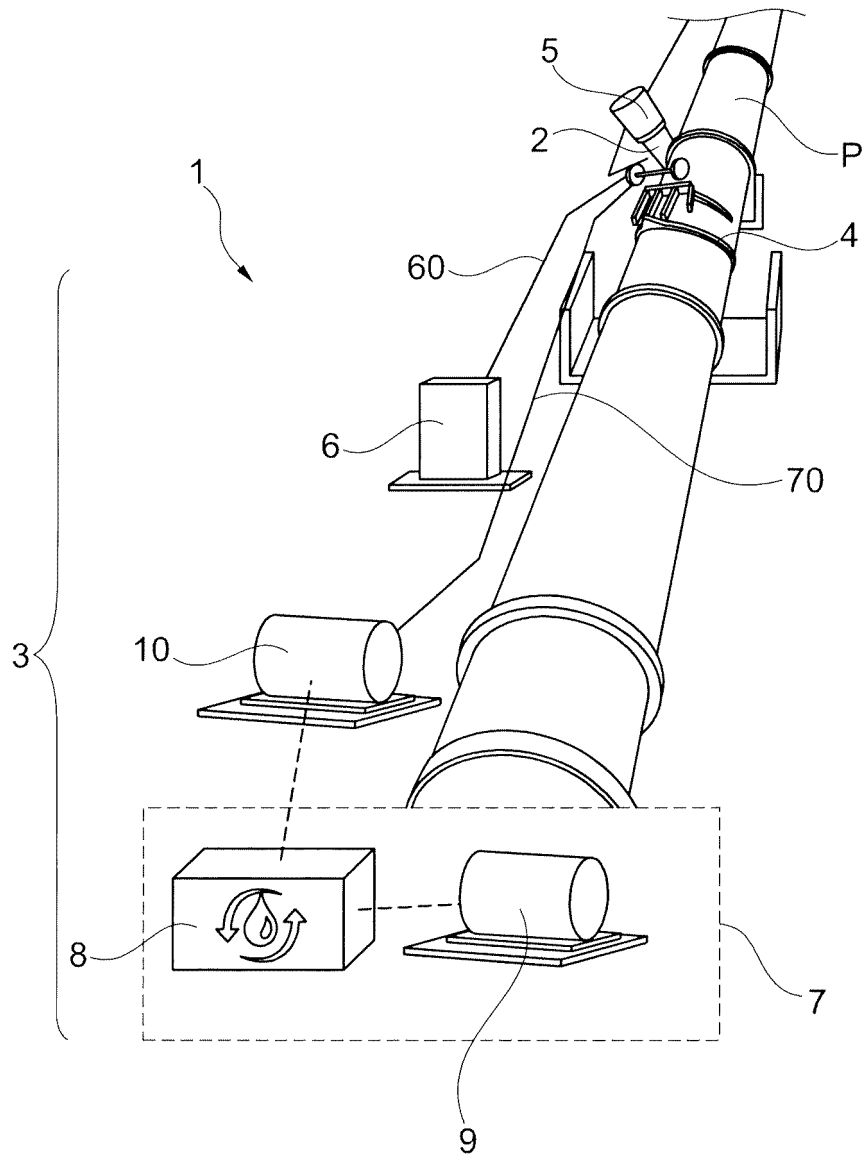


Fig. 1

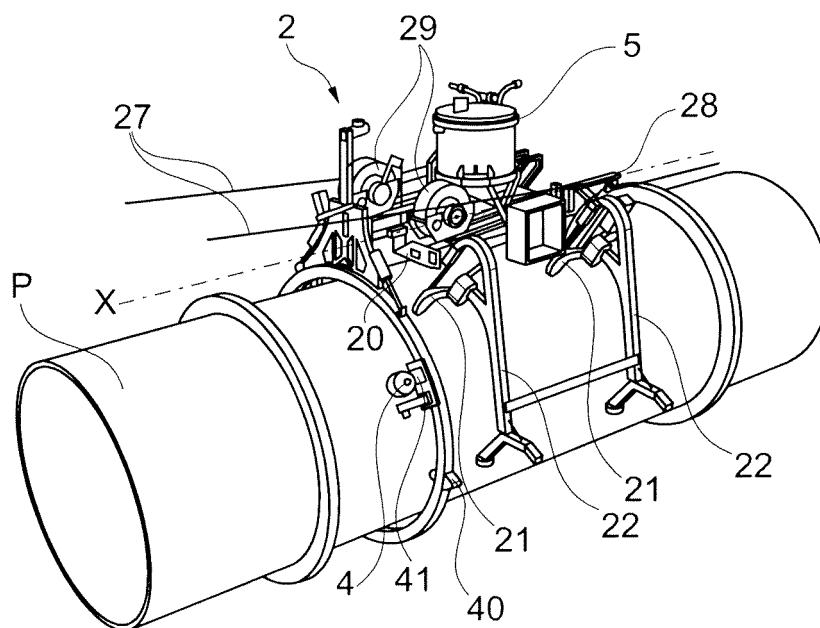


Fig. 2

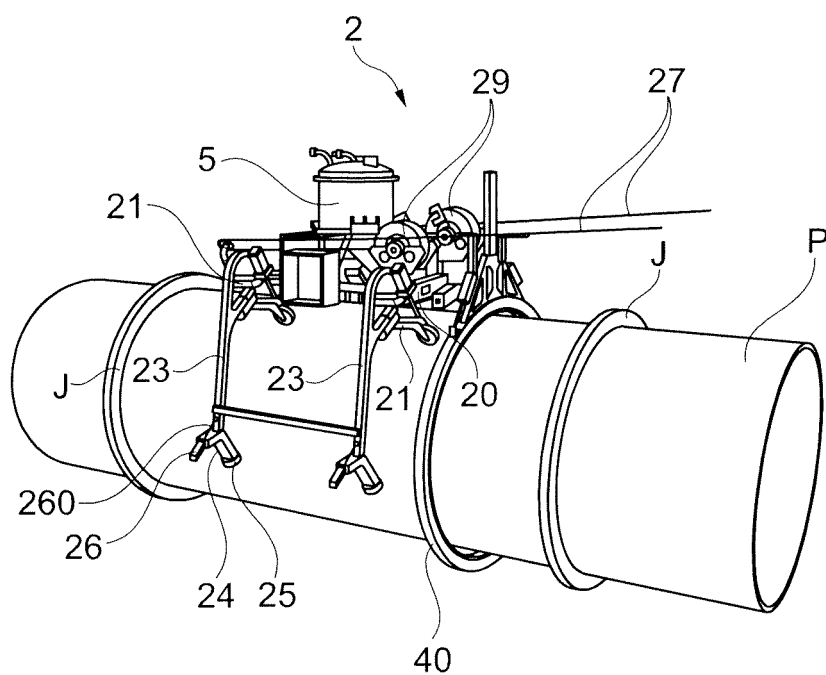


Fig. 3

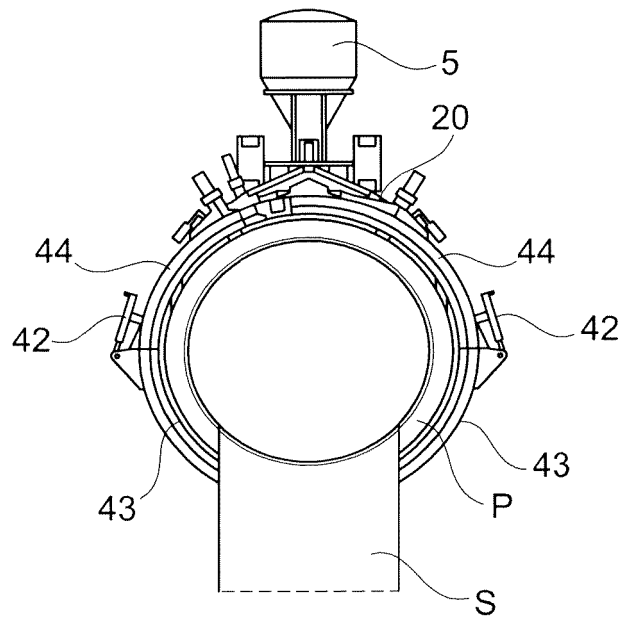


Fig. 4A

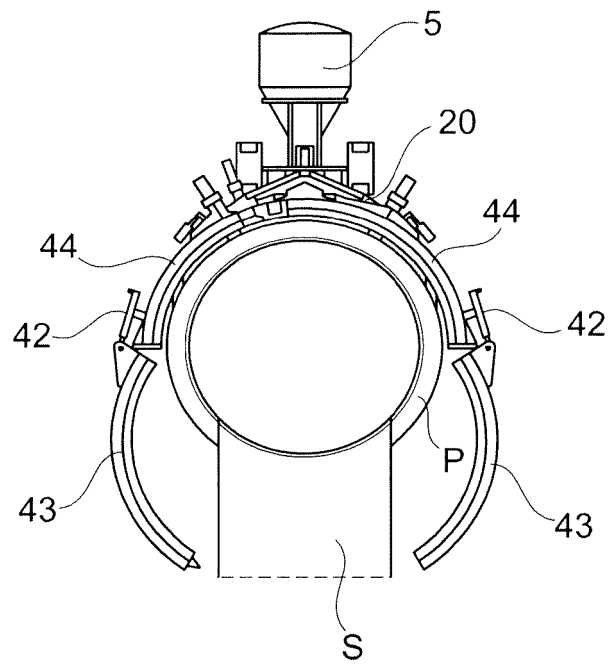


Fig. 4B

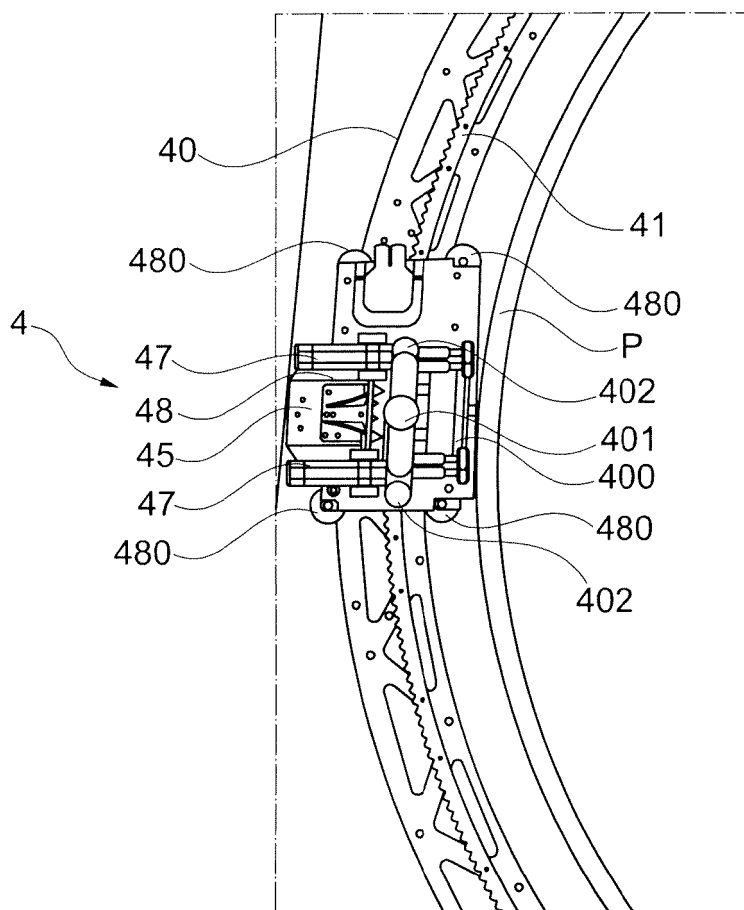


Fig. 5

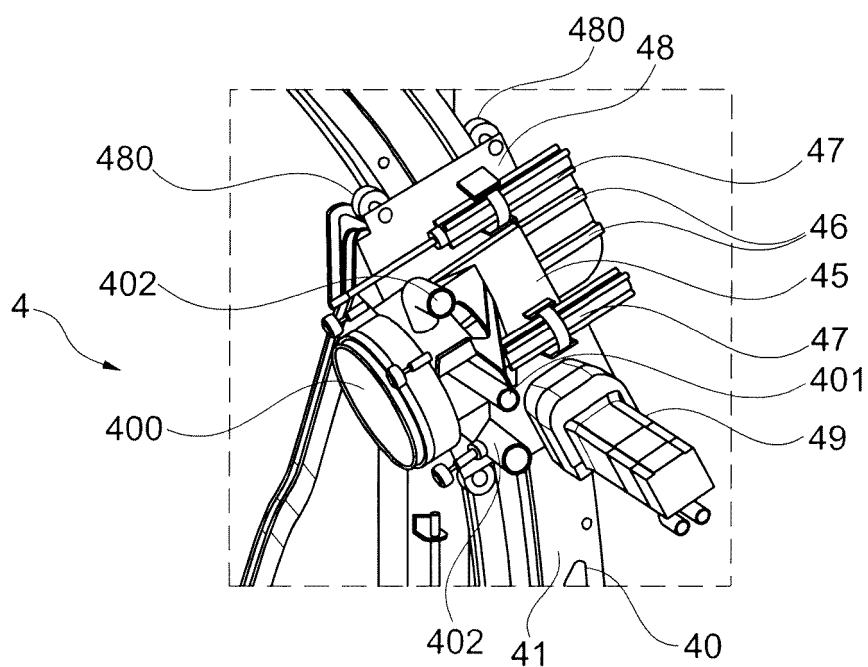


Fig. 6

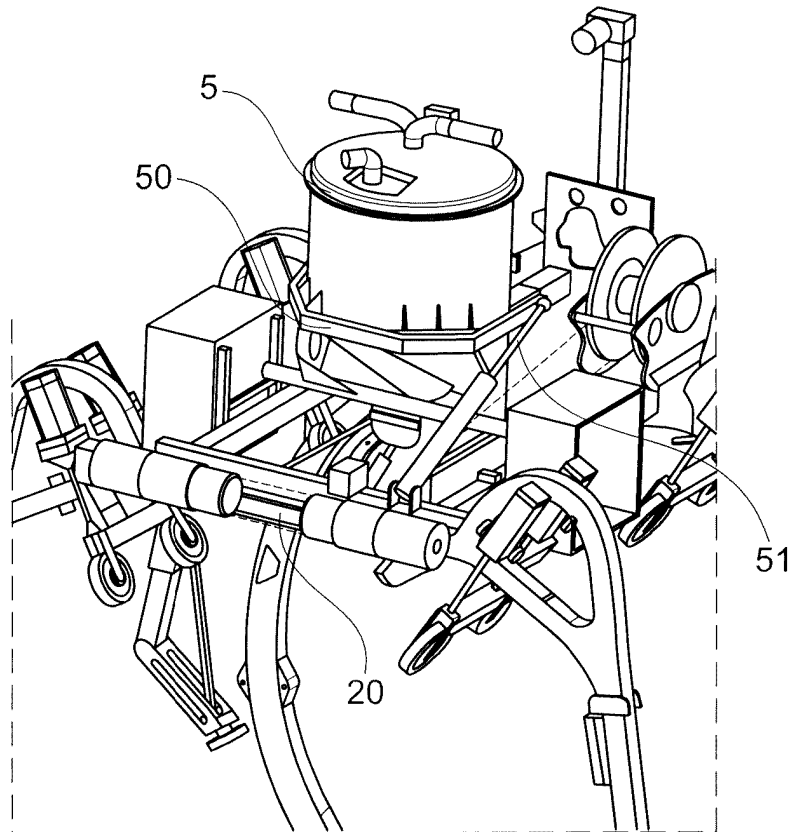


Fig. 7

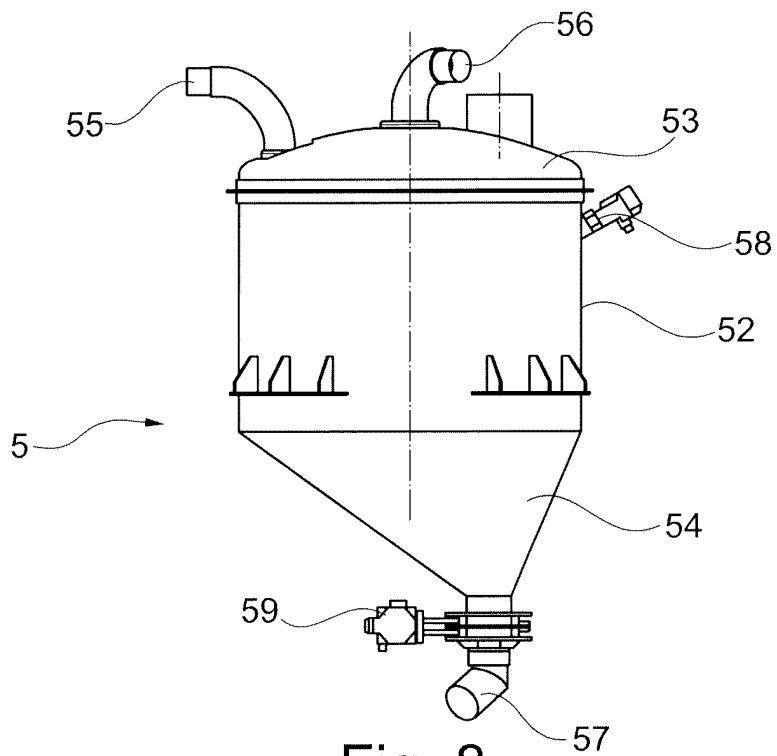


Fig. 8



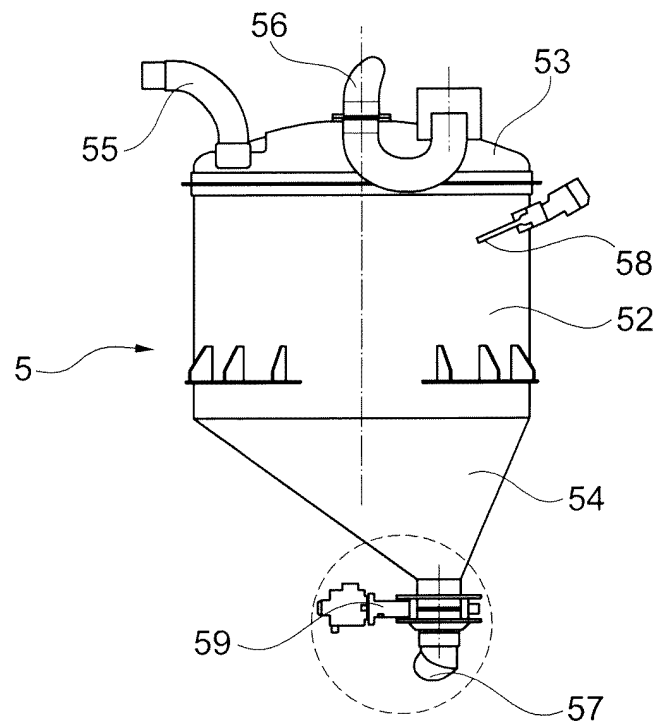


Fig. 9

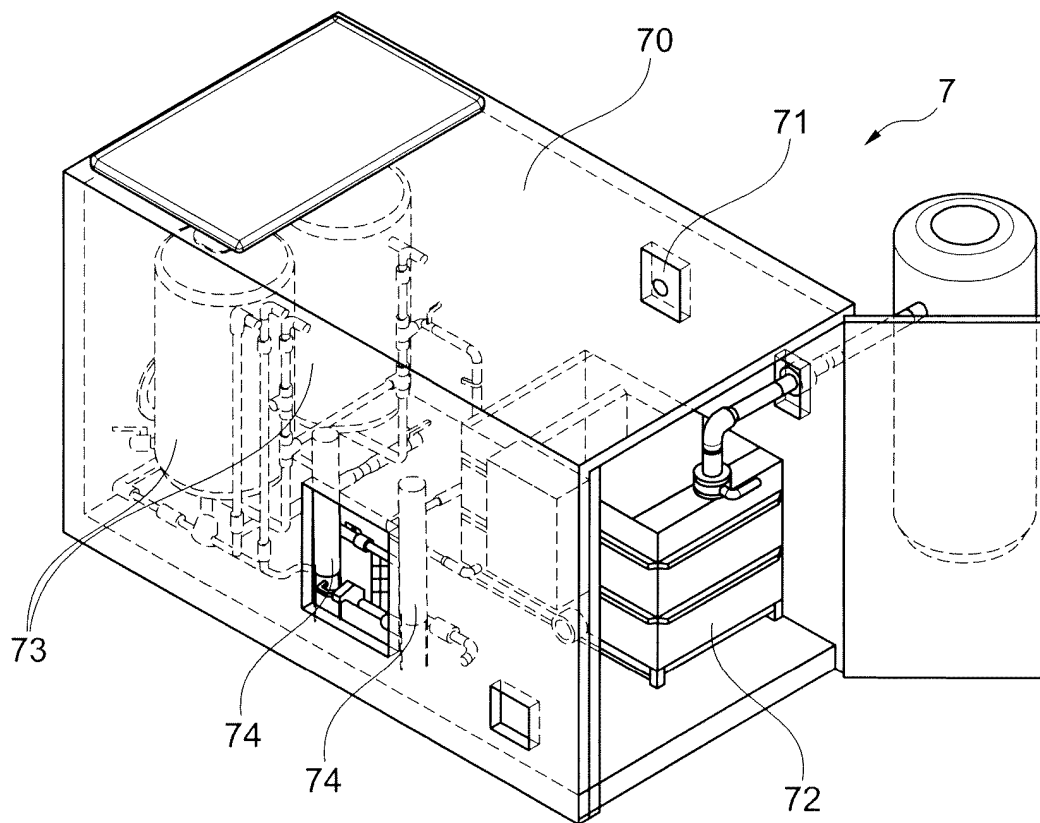


Fig. 10

**REFERENCES CITED IN THE DESCRIPTION**

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