(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 643 414 A1**

(12) **EUROPEAN PATENT APPLICATION**

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

(51) Int Cl.:
***B08B 3/02*** *(2006.01)* ***B08B 9/023*** *(2006.01)*

(21) Application number: **18425080.1**

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

(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**

(71) Applicants:
- **Impresa Donelli SRL**
  **20025 Legnano (MI) (IT)**
- **AMBPR**
  **38580 Allevard (FR)**

(72) Inventors:
- **Donelli, Piero**
  **20025 Legnano MI (IT)**
- **Donelli, Luca**
  **20025 Legnano MI (IT)**
- **Prat, Pascal**
  **07200 Lachapelle-Sous-Aubenas (FR)**
- **Bony, Olivier**
  **26400 Allex (FR)**
- **Renouard, Stéphane**
  **38580 Allevard (FR)**
- **Chini, Andrea**
  **20014 Nerviano MI (IT)**

(74) Representative: **Nony**
**11 rue Saint-Georges**
**75009 Paris (FR)**

(54) **AN ULTRA-HIGH-PRESSURE WATER JETTING (UHPWJ) HYDRO-BLASTING CLEANING SYSTEM FOR SURFACES OF VERY LARGE DIMENSIONS AND/OR OF COMPLEX SHAPES AND/OR OF DIFFICULT ACCESS AND/OR WITH A HIGH ELEVATION**

(57) The present invention concerns a Ultra-High Pressure Water Jetting (UHPWJ) hydro-blasting/cleaning system (1) for surfaces (P) of very large dimensions and/or complex shapes and/or difficult access and/or with a high elevation.

The UHPW system includes a rotating cleaning head (4) which can be kept in contact with the surface to be hydro-blasted/cleaned and sucking means which are judiciously physically separated, i.e. a cyclone type device (5) which is mounted on the mobile robot (2) 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 (6) 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.

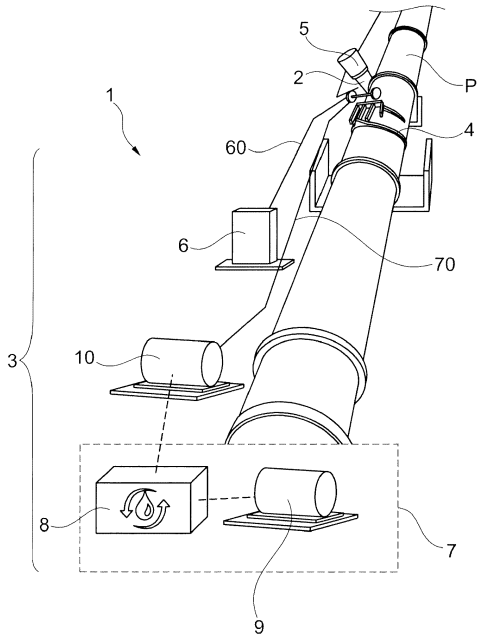


Fig. 1

EP 3 643 414 A1

## Description

### Field of the invention

**[0001]** The invention relates to the general field of the Ultra-High-Pressure Water Jetting (UHPWJ) hydroblasting/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]** However, none of the known machines has all of these advantages.

**[0035]** 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.

**[0036]** 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.

**[0037]** The invention aims to address all or part of these needs.

## Summary of the invention

**[0038]** 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 surface of very large dimensions and/or complex shapes and/or difficult access and/or with a high elevation, 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 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 scoured waste and at least one water tank connected downstream to the filtering device, in order to collect the filtered water.

**[0039]** 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.

**[0040]** 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.

**[0041]** Thus, the invention mainly consists of a UHPW 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.

**[0042]** 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 UHPWJ, allowing for transportation with standard size helicopters.

Brief description of the drawings

**[0043]** 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**

**[0044]** 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.

**[0045]** 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.

**[0046]** The terms "upstream" and "downstream" are to be understood by reference to the location of the mobile robot on the penstock to be renovated.

**[0047]** 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).

**[0048]** 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.

**[0049]** The mobile robot 2 carries a cleaning head 4 and a suction tank 5 connected to the cleaning head 4.

**[0050]** 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.

**[0051]** 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.

**[0052]** 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.

**[0053]** 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.

**[0054]** 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.

**[0055]** 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.

**[0056]** 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.

**[0057]** A water buffer tank 10 can be provided between the suction tank 5 and the filtering and collecting unit 7.

**[0058]** The unit 7 can be located at a very high distance from the mobile robot 2, typically up to 1-1,5 [km].

**[0059]** All the components of the UHPWJ system are electrically powered. Alternatively, a diesel power feeding can be foreseen.

**[0060]** 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.

**[0061]** The mobile robot 2 embeds the whole work tools and fluids required for the renovation of a penstock.

**[0062]** 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.

**[0063]** 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.

**[0064]** 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.

**[0065]** 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.

**[0066]** 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).

**[0067]** 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.

**[0068]** An electro-pneumatic cylinder 26 is mounted between an extension arm 23 and a plating arm 24.

**[0069]** 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.

**[0070]** 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.

**[0071]** Here, the frame 20 is hooked on the penstock (P).

**[0072]** 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.

**[0073]** 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.

**[0074]** 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.

**[0075]** 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.

**[0076]** A tool carriage 41 may be a rack slid ably 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.

**[0077]** The ring 40 and the circular rack 41 can be opened for the passage of the support saddles (S) of the penstock (P).

**[0078]** 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.

**[0079]** 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.

**[0080]** 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.

**[0081]** The circular rack 41 allows the circular displacement of the cleaning head around the ring 40.

**[0082]** 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.

**[0083]** 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.

**[0084]** 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.

**[0085]** 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.

**[0086]** 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.

**[0087]** 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.

**[0088]** 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.

**[0089]** The water nozzle can be feed with pressurized water by an inlet duct 401 passing through the bell 400.

**[0090]** 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.

**[0091]** 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).

**[0092]** 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.

**[0093]** Figure 7 shows an advantageous mounting of the suction tank 5 accommodating the cyclone separator, on the frame 20 of the robot 2.

**[0094]** The cyclone tank 5 is mounted with articulation on a dedicated support 50. This support is equipped with an inclinometer (not shown).

**[0095]** 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.

**[0096]** The cyclone 5 is shown alone on Figure 8.

**[0097]** 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.

**[0098]** 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.

**[0099]** A third duct 57 integral with the inferior end of the frustum-conical shape 54 is connected to the filtering unit 7.

**[0100]** 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.

**[0101]** 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.

**[0102]** 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.

**[0103]** 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.

**[0104]** The container 70 can be ventilated with exterior atmosphere by a fan 71.

**[0105]** 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.

**[0106]** At the end of the project the filtered water is finally collected in one or more tanks 8, located on site.

**[0107]** 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).

**[0108]** 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 disassembled and reassembled, allowing for transportation with standard size helicopters.

**[0109]** 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.

**[0110]** Other variants and enhancements can be provided without in any way departing from the framework of the invention.

**[0111]** 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.

**[0112]** 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) of very large dimensions and/or complex shapes and/or difficult access and/or with a high elevation, 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.

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 being mounted with translation capability on the rack between an inactive position in which the cleaning is far from the surface to be hydro-blasted/scoured and an active position in which 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 or the lifting and/or handling equipment comprising at least one pneumatic jack (47) to move the cleaning head between its active position to its inactive position and vice versa.

**5.** A UHPWJ hydro-blasting/cleaning system (1) according to Claims 2 to 4, intended to hydro-blast/clean a pipe, notably a penstock, as a surface, the frame (20) of the mobile robot 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 comprising a ring (40) fixed at the end of one of the longitudinal ends of the frame and whose inner diameter is greater than the outside of the pipe, the tool holder rack (41) being mounted with translation capability over the entire periphery of the ring.

**7.** A UHPWJ hydro-blasting/cleaning system (1) according to any preceding claims, wherein the shell and the sealing top of the cleaning head is purposely-designed in order to locate two vacuum suction ducts.

**8.** A UHPWJ hydro-blasting/cleaning system (1) according to any preceding claims, the mobile robot comprising a support for the suction tank which is levelled by an inclinometer, the suction tank 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 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 comprising at least one filter adapted to filter the sucked 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, the upstream one being a filter press whereas the downstream ones 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, 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 one being adapted to make the decantation and despoiling of the water containing the collected waste whereas the downstream ones 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), the water tank being connected to an existing draining pipe (P).

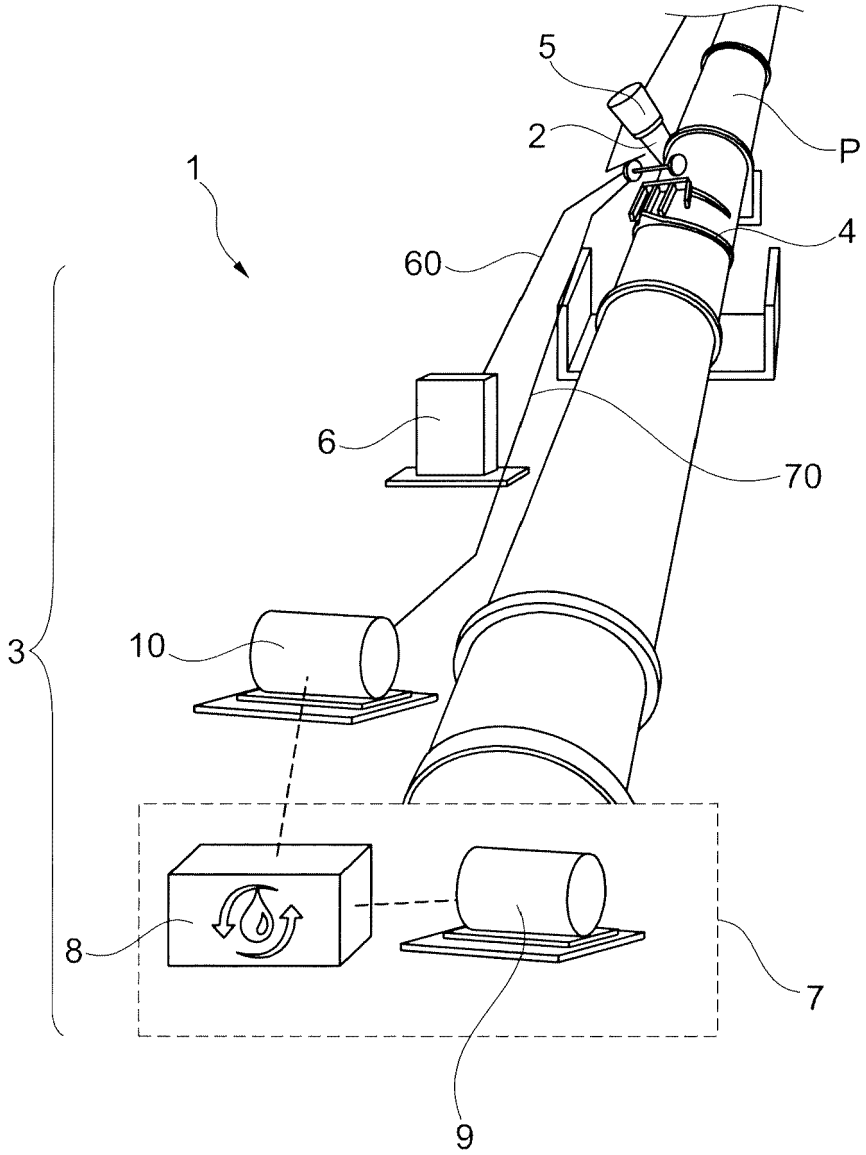


Fig. 1

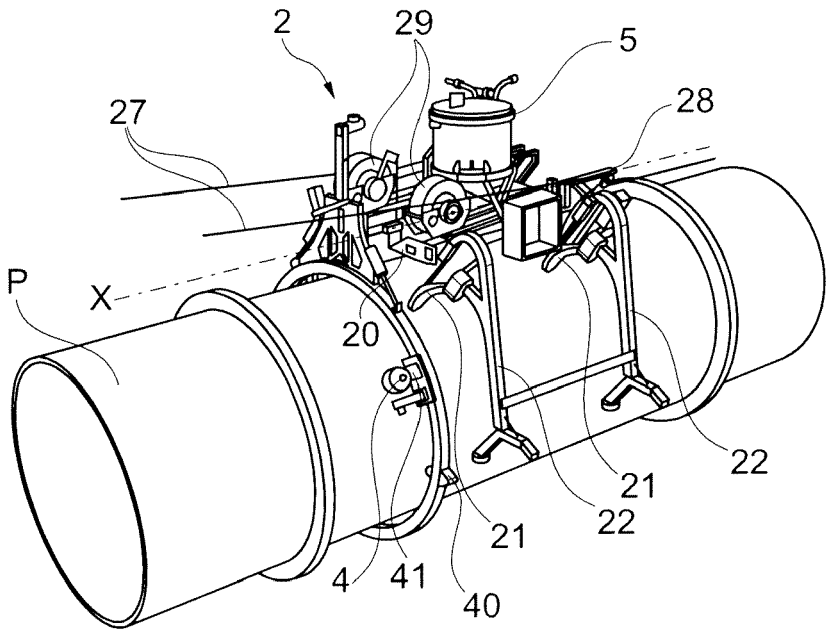
2
29
5
28
27
P
X
20
22
21
22
21
4
41
40

Fig. 2

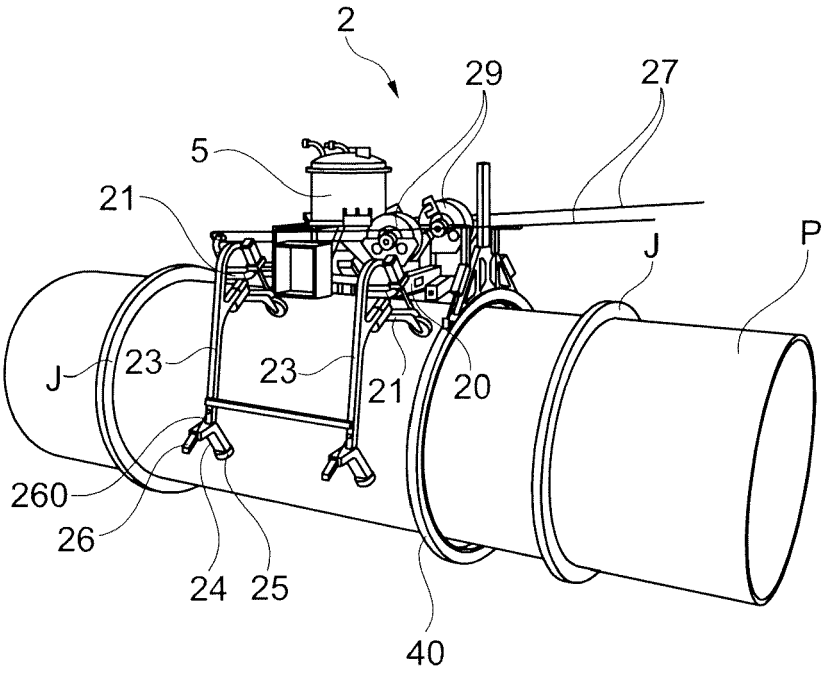
2
29
27
5
21
J
P
J
23
23
21
20
260
26
24
25
40

Fig. 3

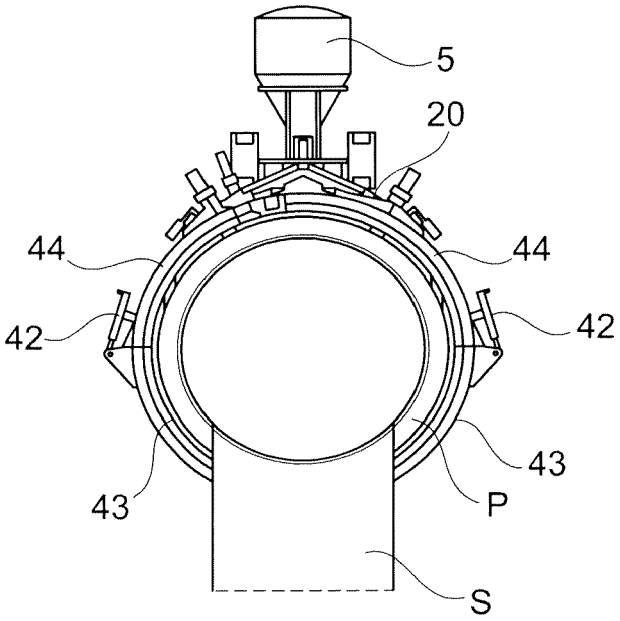


Fig. 4A

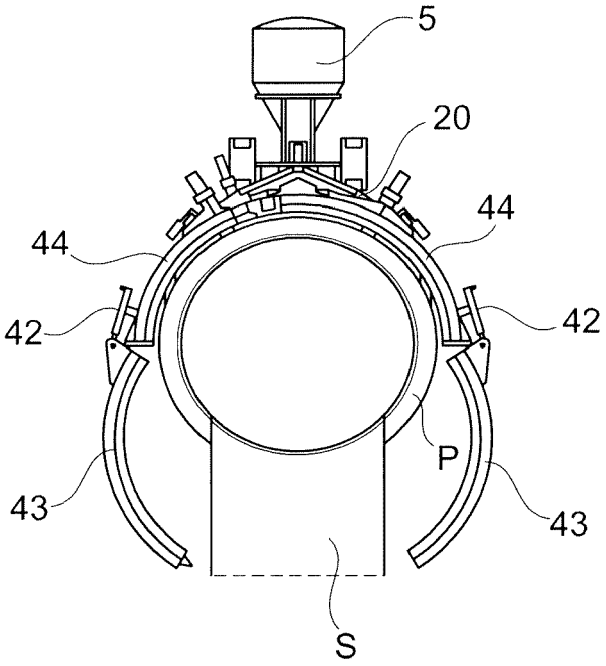


Fig. 4B

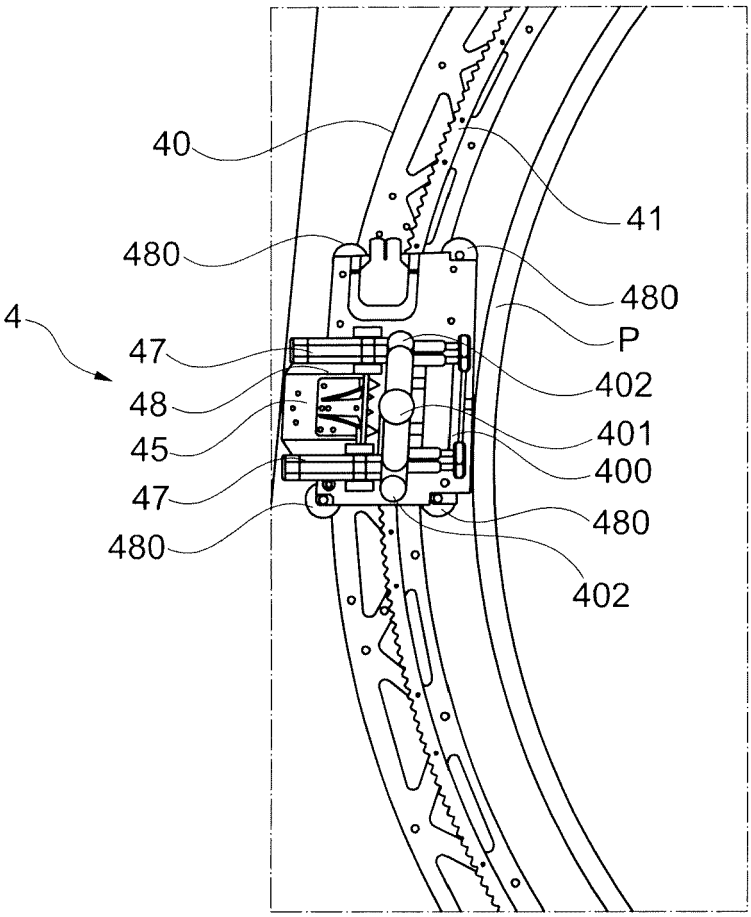
40
41
480
480
4
P
47
402
48
401
45
400
47
480
480
402

Fig. 5

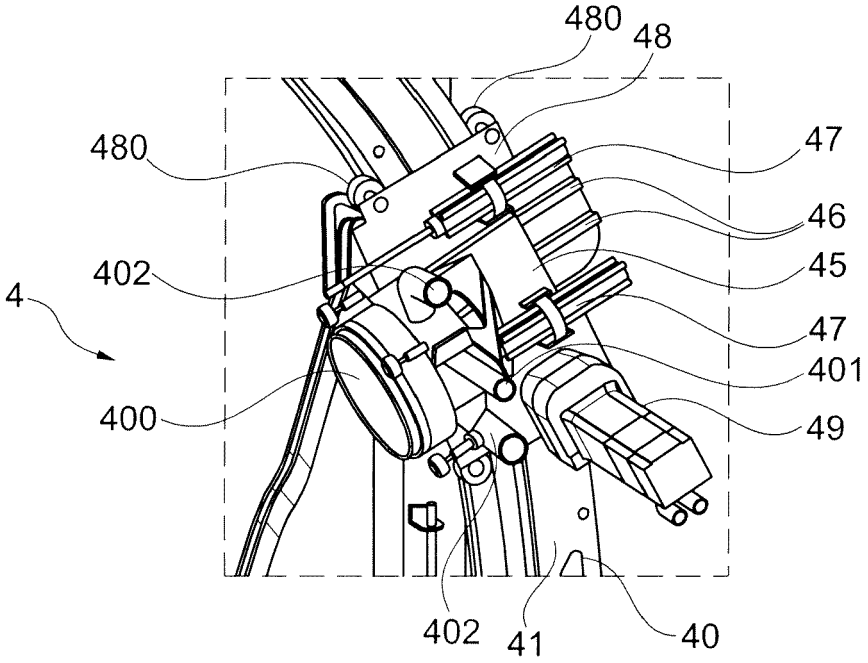
480
48
480
47
46
402
45
4
47
401
400
49
402
41
40

Fig. 6

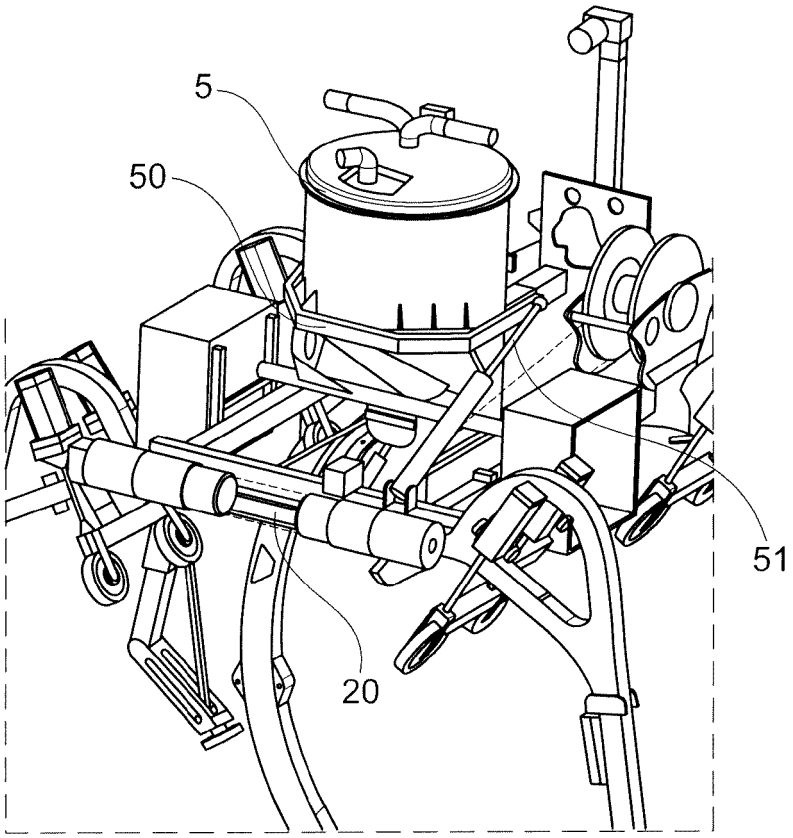


Fig. 7

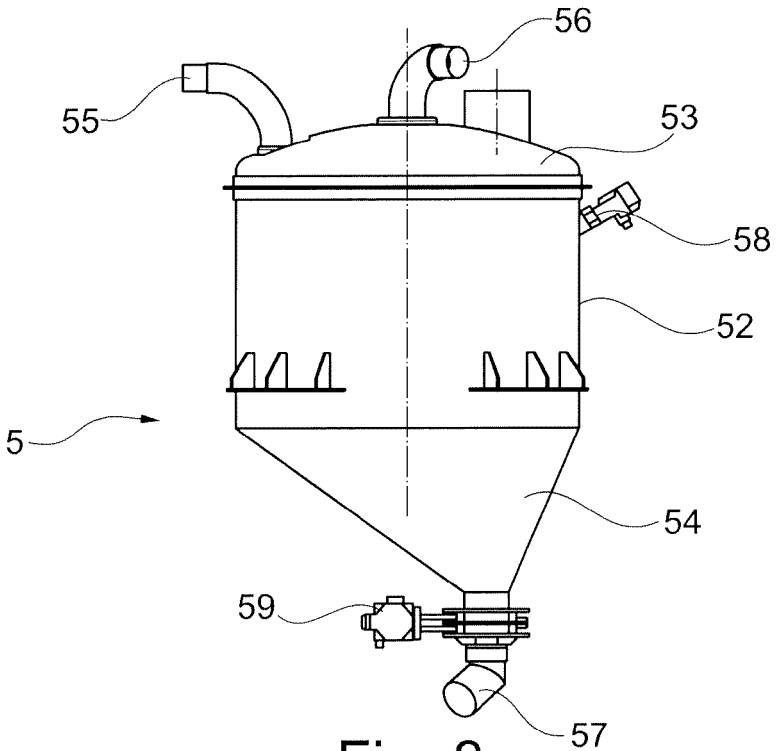


Fig. 8

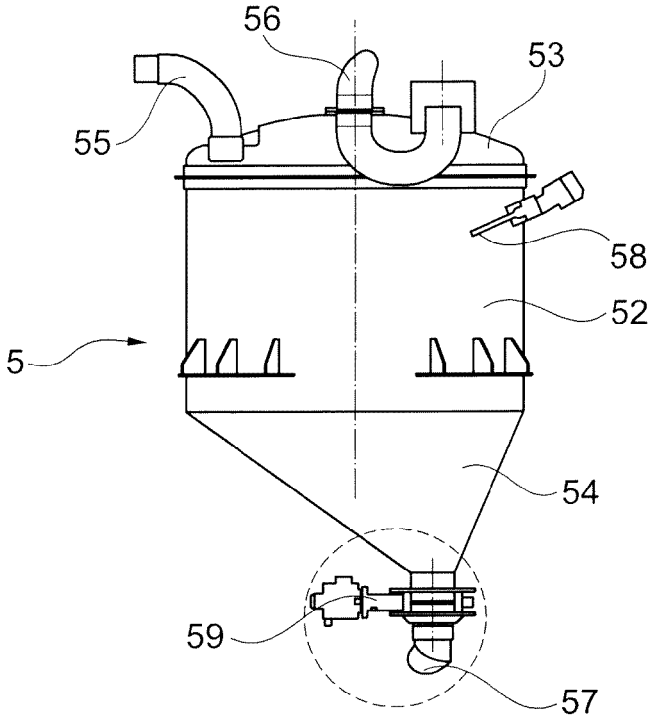


Fig. 9

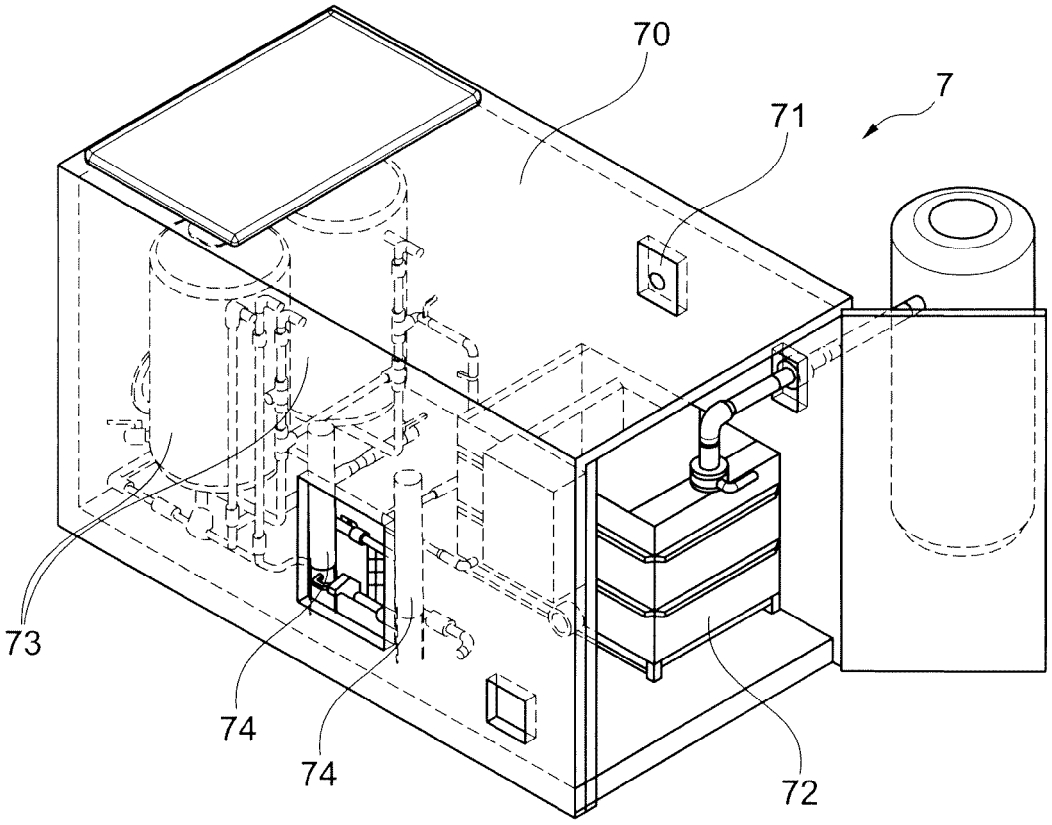


Fig. 10

Europäisches Patentamt
European Patent Office
Office européen des brevets

# EUROPEAN SEARCH REPORT

Application Number
EP 18 42 5080

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (IPC) |
|---|---|---|---|
| A | US 2016/016205 A1 (PERI BAT [FR])<br>21 January 2016 (2016-01-21)<br>* paragraph [0065] - paragraph [0073]; figures 1-4,9-13 * | 1-4,9-14 | INV.<br>B08B3/02<br>B08B9/023 |
| A | WO 2012/094767 A1 (AUTOMATIC COATING LTD [CA]; BAMFORD BRAD [CA])<br>19 July 2012 (2012-07-19)<br>* paragraph [0079] - paragraph [0083]; figures 1-5,14 * | 1-6 | |
| A | US 5 743 969 A (LAWLER OLIVER WAYNE [US])<br>28 April 1998 (1998-04-28)<br>* SUMMARY OF THE INVENTION; figures 1,4,7,12-14 * | 1-6 | |
| A | EP 0 710 511 A1 (CRC EVANS REHABILITATION SYST [US]) 8 May 1996 (1996-05-08)<br>* column 24, line 32 - column 27, line 14; figures 1-4 * | 1-6 | |
| A | US 2011/030740 A1 (BAMFORD BRAD [CA])<br>10 February 2011 (2011-02-10)<br>* paragraph [0044] - paragraph [0056]; figures 1-10 * | 1-6 | TECHNICAL FIELDS SEARCHED (IPC)<br>B08B |
| A | DE 44 04 230 A1 (MAX STEINHART GMBH PFLASTER UN [DE])<br>17 August 1995 (1995-08-17)<br>* column 3, line 44 - column 4, line 15; figures 4,5 * | 1,7 | |
| A | FR 3 036 635 A1 (JMC ENVIRONNEMENT [FR])<br>2 December 2016 (2016-12-02)<br>* page 12, line 27 - page 19, line 22; figures 1,2,5,6 * | 1,9,10, 12 | |

-/--

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| The Hague | 25 April 2019 | Cassiat, Clément |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

Europäisches Patentamt
European Patent Office
Office européen des brevets

# EUROPEAN SEARCH REPORT

Application Number
EP 18 42 5080

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (IPC) |
|---|---|---|---|
| A | US 5 136 969 A (CHAPMAN GORDON R [US]) 11 August 1992 (1992-08-11) * column 6, line 50 - column 7, line 29; figures 1-3 * | 1-3 | |
| A | FR 2 750 898 A1 (COGEMA [FR]) 16 January 1998 (1998-01-16) * page 7, line 17 - page 13, line 31; figures 1-2 * | 1,9-14 | |
| A | FR 2 698 021 A1 (ONET [FR]) 20 May 1994 (1994-05-20) * page 6, line 35 - page 11, line 21; figures 1-2 * | 1,9-14 | |
| A | WO 2015/164809 A1 (WATERBLASTING LLC [US]) 29 October 2015 (2015-10-29) * page 5, line 1 - page 6, line 7; figures 1,10 * | 1,9-14 | |
| A | EP 0 670 781 A1 (SJOEBERG STAFFAN [SE]) 13 September 1995 (1995-09-13) * column 3, line 5 - line 46; figures 1-5 * | 1 | TECHNICAL FIELDS SEARCHED (IPC) |

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| The Hague | 25 April 2019 | Cassiat, Clément |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

## ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 18 42 5080

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

25-04-2019

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| US 2016016205 A1 | 21-01-2016 | AU 2014224418 A1 | 24-09-2015 |
| | | CA 2903253 A1 | 12-09-2014 |
| | | EP 2964400 A1 | 13-01-2016 |
| | | FR 3002849 A1 | 12-09-2014 |
| | | FR 3002866 A1 | 12-09-2014 |
| | | JP 2016515918 A | 02-06-2016 |
| | | KR 20150126366 A | 11-11-2015 |
| | | US 2016016205 A1 | 21-01-2016 |
| | | WO 2014135819 A1 | 12-09-2014 |
| WO 2012094767 A1 | 19-07-2012 | CA 2764099 A1 | 14-07-2012 |
| | | US 2012272897 A1 | 01-11-2012 |
| | | US 2015183008 A1 | 02-07-2015 |
| | | US 2016114363 A1 | 28-04-2016 |
| | | US 2018354004 A1 | 13-12-2018 |
| | | WO 2012094767 A1 | 19-07-2012 |
| US 5743969 A | 28-04-1998 | US 5615696 A | 01-04-1997 |
| | | US 5743969 A | 28-04-1998 |
| EP 0710511 A1 | 08-05-1996 | AU 704110 B2 | 15-04-1999 |
| | | CA 2157138 A1 | 22-04-1996 |
| | | DE 69509471 D1 | 10-06-1999 |
| | | DE 69509471 T2 | 07-10-1999 |
| | | EP 0710511 A1 | 08-05-1996 |
| | | JP H08206619 A | 13-08-1996 |
| | | US 6461231 B1 | 08-10-2002 |
| US 2011030740 A1 | 10-02-2011 | CA 2712387 A1 | 06-02-2011 |
| | | US 2011030740 A1 | 10-02-2011 |
| DE 4404230 A1 | 17-08-1995 | NONE | |
| FR 3036635 A1 | 02-12-2016 | NONE | |
| US 5136969 A | 11-08-1992 | US 5136969 A | 11-08-1992 |
| | | US 5238331 A | 24-08-1993 |
| FR 2750898 A1 | 16-01-1998 | NONE | |
| FR 2698021 A1 | 20-05-1994 | NONE | |
| WO 2015164809 A1 | 29-10-2015 | AU 2015249256 A1 | 08-12-2016 |
| | | EP 3134216 A1 | 01-03-2017 |
| | | WO 2015164809 A1 | 29-10-2015 |

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

## ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 18 42 5080

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

25-04-2019

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| EP 0670781 A1 | 13-09-1995 | AT 159461 T | 15-11-1997 |
| | | AU 676243 B2 | 06-03-1997 |
| | | BR 9307518 A | 31-08-1999 |
| | | CA 2150011 A1 | 09-06-1994 |
| | | DE 69314805 D1 | 27-11-1997 |
| | | DE 69314805 T2 | 12-02-1998 |
| | | DK 0670781 T3 | 20-07-1998 |
| | | EP 0670781 A1 | 13-09-1995 |
| | | ES 2110210 T3 | 01-02-1998 |
| | | FI 952525 A | 24-05-1995 |
| | | GR 3025921 T3 | 30-04-1998 |
| | | JP 3184225 B2 | 09-07-2001 |
| | | JP H08503900 A | 30-04-1996 |
| | | KR 100267473 B1 | 01-11-2000 |
| | | NO 305542 B1 | 21-06-1999 |
| | | PL 309036 A1 | 18-09-1995 |
| | | RU 2117583 C1 | 20-08-1998 |
| | | US 5603775 A | 18-02-1997 |
| | | WO 9412349 A1 | 09-06-1994 |

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

## REFERENCES CITED IN THE DESCRIPTION

*This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.*

### Patent documents cited in the description


- US 5528789 A **[0026]**
- JP 2001096246 B **[0026]**
- CN 10169890 **[0026]**
- US 6026538 A **[0028]**