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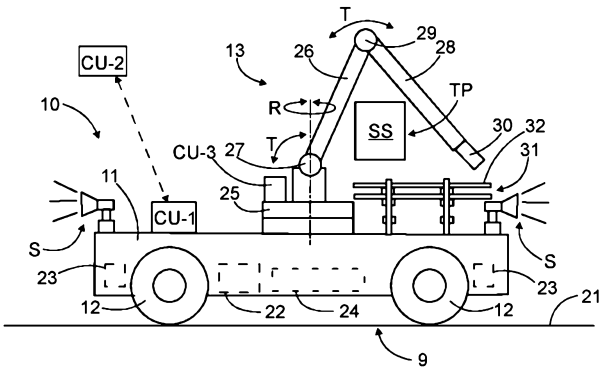
Laite ja menetelmä soodakattilan sulakourujen puhdistamiseksi
Anordning och förfarande för att rengöra smältrännor i en sodapanna
APPARATUS AND METHOD FOR CLEANING SMELT SPOUTS OF RECOVERY BOILER

(57) Tiivistelmä - Sammandrag - Abstract

Keksintö koskee laitteistoa ja menetelmää soodakattilan sulakourujen puhdistamiseksi. Keksintö koskee lisäksi järjestelyä soodakattilassa. Soodakattila (1) käsittää useita sulakouruja (6), jotka puhdistetaan moottoroitujen puhdistusyksikköjen (13) avulla. Puhdistusyksiköt on asennettu vaunuihin (11) niiden liikuttamiseksi sulakourujen välillä. Vaunut on varustettu ohjattavilla liikutuselimillä (12, 33), ja ne ovat siten ohjattavissa vapaasti kulkupinnalla. Laitteiston ohjausjärjestelmä käsittää paikannusjärjestelmän vaunun ohjaamiseksi kuvitteellista kulkureittiä pitkin kohdepisteisiin (TP).

An apparatus and method for cleaning smelt spouts of a recovery boiler. The invention further relates to an arrangement in the recovery boiler. The recovery boiler (1) comprises several smelt spouts (6) which are cleaned by means of motorized cleaning units (13). The cleaning units are mounted on carriers (11) for moving them between the smelt spouts. The carriers are provided with steerable moving members (12, 33) and are thereby freely steerable on a driving surface. A control system of the apparatus comprises a positioning system for guiding the carrier along an imaginary driving path to target points (TP).



APPARATUS AND METHOD FOR CLEANING SMELT SPOUTS OF RECOVERY BOILER

Background of the invention

The invention relates to an apparatus for cleaning smelt spouts of a recovery boiler.

The invention further relates to an arrangement in a recovery boiler and a method of cleaning smelt spouts.

The field of the invention is defined more specifically in the preambles of the independent claims.

Recovery boilers, such as soda recovery boilers, are used in recovery cycles of sulfate and other Na-based pulping processes for waste liquor containing cooking chemicals. By means of the recovery boilers the chemicals may be processed into a form suitable for recovery purposes and for producing heat. Organic substances dissolved during the digestion in the waste liquor are combusted in the furnace of the boiler generating heat. The heat is utilized on one hand for converting inorganic compounds of the waste liquor back into chemicals to be used in cooking, and on the other hand for generating steam. The inorganic substance in the waste liquor melts in the high temperature of the furnace and flows as smelt onto the bottom of the furnace. From the bottom of the boiler the chemical smelt is led via smelt spouts into a dissolving tank, where it is dissolved in liquid for forming green liquor. The green liquor is then led to a causticizing plant, where white liquor is produced therefrom.

When the smelt flows out of the furnace and down along the smelt spout, cinder is formed that adheres to the inside and bottom of the spout. The cinder may harden and accumulate to the spout and may also plug the smelt opening. In order to keep the outlet opening free from plugs and the smelt spout clean so that the smelt may flow to the dissolving tank in a correct way, it is necessary to clean the spout and the outlet opening every now and

20175563 PRH 16-06-2017

then. Conventionally, this has been effected in a manual way by means of rods.

Document US-5542650-A discloses a cleaning device comprising motorized means for performing mechanical cleaning or rodding. Further, EP-1914477-B1 discloses a cleaning apparatus capable of moving between the smelt spouts. However, the known cleaning devices have shown to contain some disadvantages.

Brief description of the invention

An object of the invention is to provide a novel and improved apparatus and method for cleaning smelt spouts of a recovery boiler. The invention further relates to a novel and improved arrangement in a recovery boiler.

The apparatus according to the invention is characterized by the characterizing features of a first independent apparatus claim.

The arrangements according to the invention are characterized by the characterizing features of a second and third independent apparatus claims.

The method according to the invention is characterized by the charactering features and steps of an independent method claim.

An idea of the disclosed solution is that at least one freely movable carrier is arranged to be driven automatically at a work area of a recovery boiler. The carrier is configured to be navigated inside the work area and to be positioned to desired target points. The carrier is provided with several moving elements supported on a driving surface of the work area and at least some of the moving elements are steerable enabling the free driving. At least one control unit is configured to determine a movement path for driving the carrier at the work area. The control unit is configured to navigate the carrier along the created movement path to the desired target points at the work site. The at least one control unit

also generates control commands for steering actuators of the carrier in order to control the driving.

Further, the carrier may be provided with one or more cleaning units for cleaning smelt spouts of the recovery boiler. In addition to, or alternatively, the carrier may comprise one or more other devices or units for executing operational tasks at desired target points inside the work area.

An advantage of the disclosed solution is that the carrier may be positioned freely to any desired target or working point inside the work area. Thereby the positioning system is flexible and changes to working points and driving arrangements are easy to make. Since the positioning of the carrier may be executed without any fixed steering structures, such as guide rails, the system is also easy to implement. Mounting of the system is quick and it may also be retrofitted easily to the existing recovery boilers.

Thanks to the automated apparatus, efficiency and productivity of the system may be increased, as well as operator safety. The system is also versatile since the carrier may be equipped with several different operating devices and tools so that the apparatus may be configured to execute several different tasks inside the working area.

According to an embodiment, the apparatus is intended especially for cleaning smelt spouts of the recovery boiler. Thus, one or more motorized cleaning units are supported on the carrier at least during the transfer drive executed between the smelt spouts. The carrier may provide support for the cleaning unit also during the cleaning process, or alternatively, the cleaning unit is provided with own support means or is supported to other external support structures. The cleaning unit removes efficiently and gently smelt deposits from the smelt spouts whereby trouble free and

safe operation of the recovery boiler is ensured and the smelt spouts are not hampered during the cleaning. The cleaning procedure may be taught and stored for the cleaning unit.

According to an embodiment, the cleaning unit comprises one or more industrial robots, each of which is provided with a turning base and two or more arms connected by means on joints to the base and to each other. At the end of an outermost arm is a tool holder or gripping device for receiving different kind of tools.

According to an embodiment, the work area of the apparatus comprises a restricted area at the recovery boiler. The work area may include only a service platform locating adjacent the smelt spouts, or the work area may be larger and may include defined areas outside the smelt spout area. Thus, the apparatus may have target points and operational tasks elsewhere too.

According to an embodiment, the apparatus may comprise one single control unit configured to control driving of the carrier, positioning and navigation of the carrier, and further, to control work cycle of the cleaning unit. Alternatively, the apparatus may comprise dedicated control units for the carrier and the cleaning unit. Then the apparatus may comprise a first control unit for controlling the driving and positioning of the carrier, and a second control unit for controlling the cleaning unit and any other operational devices arranged on the carrier. The control system may comprise one or more on-board control units, and alternatively or in addition to, the apparatus may be in connection with one or more external control devices through wireless data connections. Thereby, it possible to produce navigation data external to the apparatus, for example.

According to an embodiment, the moving elements are steered during the transfer drive so that the direction of the transfer movement may deviate from linear

movement. In other words, the carrier may be driven along movement paths comprising non-linear sections, such as curved or angular driving sections. Further, the apparatus may be configured to detect physical objects on its movement path and may dodge the physical objects by executing steering movements.

According to an embodiment, the moving element is a wheel or corresponding rolling element. Thus, in this embodiment the apparatus may be a wheeled vehicle comprising several wheels. The wheels may be supported against a driving surface. An upper surface of a service platform of the recovery boiler may serve as the driving surface on which the apparatus is driven. The driving surface may be a flat surface and it may have a solid or grid-like configuration. At least some of the wheels, or all of them, may be steerable whereby the carrier may be driven inside the work area in an accurate and operationally flexible manner to target points being freely selected or determined. The steerable wheels may be turned relative to a body of the carrier.

According to an embodiment, the carrier comprises several wheels outer surfaces of which are provided with several rollers. The rollers are angled relative to the driving direction and may be rotated around their central axis. In this embodiment the wheels are not turned relative to the carrier, but instead the steering of the carrier is executed by controllably rotating the rollers of all or selected wheels. An advantage of this embodiment is that the carrier is easily steerable in narrow spaces. Further, the carrier may turn at the current position without moving forwards or backwards.

According to an embodiment, the moving element of the carrier is a crawler track. Then, the carrier comprises one or more crawler tracks supportable against the driving surface. An advantage of the tracked vehicle is that it may be driven also on uneven and dirty driving

20175563 PRH 16-06-2017

surfaces. The carrier comprising crawler tracks may also be driven freely on the driving surface.

According to an embodiment, the carrier is an autonomously operating wheeled platform. A top surface of the platform is provided with one or more connecting points and means for connecting at least one operable device on the platform. Thereby, the platform may be provided with at least one industrial robot. Alternatively, or in addition to, the platform may be equipped with a transfer device or a monitoring device, for example. The device being carried by the platform may be changed according to a need, whereby the platform may serve as a multipurpose transfer device.

According to an embodiment, the target points used in the navigation and path planning may be pre-determined and input to the at least control unit of the system. Coordinates of the target points may be retrieved form a data file or input by using input means. Alternatively, the target points may be taught for the system by driving the carrier to the desired target points and then storing the position. Further, the target points may be updated and position data of one or more additional target points may be input to the control unit later. An advantage of this embodiment is that work cycle of the transfer drive and routing may be flexibly adjusted according to need.

According to an embodiment, the apparatus is provided with at least one control unit which comprises a positioning system. The positioning system provides the control unit with data on current position and direction of the carrier relative to position and direction of one or more target points being input to the control unit. The target points may be taught for the system or coordinates of the target points may be input by means of input means. The control unit is configured to generate one or more virtual movement paths for the transfer drive of the carrier and is configured to generate steering commands

for automatically steering the carrier along the generated virtual movement path to the target points. An advantage of this embodiment is that the control unit may generate automatically a collision free movement path for driving the carrier to any desired target point at the work area. The virtual movement path may also be updated during the drive. The carrier or mobile platform may navigate autonomously inside the work area.

According to an embodiment, the apparatus comprises a positioning system provided with at least one scanning device for scanning surroundings of the apparatus. There may be one rotating scanner device covering the entire surrounding, or alternatively several scanning devices arranged at front and rear parts of the carrier. All corners of the carrier may be equipped with the scanning devices, for example. The scanning results may be transmitted via wired or wireless data transmission path to the control unit for further processing them. The control unit is configured to determine the current position and direction of the apparatus in a coordinate system in response to the generated scanning data received from the scanning device. The control unit is provided with position and direction data on the target points and is configured to generate navigation instructions towards them. An advantage of the use of the scanners is that they provide accurate measuring data and are operable also in harsh and dirty conditions. Nowadays the scanning devices are also small sized and inexpensive, whereby use of several scanning devices is possible.

According to an embodiment, the scanning device of the positioning system may be a laser scanner or radar. Operation of the scanning device may be based on time-of-flight principle (ToF), for example.

According to an embodiment, the generated scanning data is also utilized for collision prevention. The control unit is configured to detect possible physical

obstacles at the work site and is configured to generate a collision free movement path or to execute collision avoidance measures to prevent collisions. The control unit may be provided with a collision prevention algorithm or program, which is executed in a processor of the control unit. When detecting possible collision the control unit may amend the movement path and execute steering movements for getting around the detected obstacle, or alternatively, the control unit may stop the carrier until the route is free to be driven. Thanks to the collision prevention system, safety of the apparatus is improved. In some cases it may be even possible to avoid need for physical barriers limiting access to the working area of the apparatus.

According to an embodiment, the positioning system of the apparatus may comprise a dead reckoning system for sensing driven distance and orientation sensors for sensing driving direction. The apparatus may locate itself by means of the dead reckoning system alone or together with one or more scanning devices. The dead reckoning system may comprise one or more sensing devices for detecting rotation of wheels, whereby the travelled distance may be calculated when outer circumferences of the wheels are known. Heading of the carrier may be detected by means of gyroscopes, for example. The current position and direction of the carrier may then be computed in the control unit and may be compared to the input target position for generating steering commands for steering actuators.

According to an embodiment, the positioning of the apparatus is based on a 3D map and 3D scanning. The control unit is provided with an environmental 3D map of the working area of the apparatus together with position data on the predetermined target positions. The control unit is also provided with 3D scanning data received from the scanners and is configured to generate 3D view of the

20175563 PRH 16-06-2017

surroundings of the apparatus when driving at the working area. The scanning data may comprise point cloud data with several points provided with coordinates. Further, the control unit is configured to compare the current 3D view to the 3D map for determining the current position and direction of the apparatus. The control unit may be arranged to search where the scanned point cloud data matches best with the point cloud of the 3D map and may select the matching position and direction to represent the current pose. Thereafter, the control unit may compare the current pose to the target point and may generate a virtual drive path to reach the target point. The control unit may update the 3D map on the basis of the findings of the 3D scanning whereby accuracy of the 3D map may be increased continuously. Furthermore, the navigation system may create the 3D map of the surroundings by means of the SLAM method (Simultaneous Localization and Mapping), whereby the driving may be initiated even without any pre-created 3-D map.

According to an embodiment, the positioning is carried out without fixed positioning infrastructure at the working area. In other words, the positioning system is infra-free since it is able to position the carrier without artificial markings at the work area. The infra-free positioning may be based on use of the above disclosed 3D mapping and scanning, for example. Since no special positioning means are required at the working area, the infra-free positioning is easy and fast to implement and update.

According to an embodiment, the positioning of the apparatus is based on artificial positioning aids arranged inside the working area. Then, the positioning system of the apparatus may comprises one or more detecting devices for detecting reference markings at reach of the apparatus. The control unit may determine the current position and orientation of the apparatus on the basis of

the detection data and is configured to navigate the carrier in response to the detected reference markings. The artificial positioning aids may be fastened to walls, ceiling or floor of the working area.

According to an embodiment, the apparatus comprises at least one detecting device for detecting visual reference markings. The target point may be provided with visual position markings, for example. Position of the visual reference or position marking may be known by the control unit. The visual position marking may comprise identification data. In connection with the visual reference marking may be a bar code, a QR code or any other machine readable code for providing additional information for navigation or for executing the work tasks.

According to an embodiment, the apparatus comprises at least one detecting device for detecting a reference line arranged at the work site of the apparatus. The reference line may be arranged in connection with the driving surface or in connection with a wall structure of the recovery boiler, for example. The reference line may be detected visually or magnetically, for example. The reference line may be considered to be a virtual track followed by the cleaning apparatus. The reference line may comprise straight, angular and curved parts, and it may be a continuous line or broken line.

According to an embodiment, the apparatus comprises at least one detecting device capable for receiving radio signals transmitted by RFID -tags or base stations, for example. Thereby, the apparatus may be positioned and navigated by receiving signals from electronic devices the positions of which are known by the control unit.

According to an embodiment, one or more of the target points locating at the work area may comprise mechanical docking means. The docking means may comprise

stationary docking members configured to receive an aligning member of the carrier. The carrier may be positioned to the target point in accordance with the positioning arrangements disclosed already above. However, the mechanical docking means may finalize the positioning at the target point and may thereby secure correct positioning of the carrier. Further, the docking means may be designed to provide support for the apparatus during execution of the work cycle. The docking means may comprise a pin and a hole, for example. Alternatively the target point may comprise a guide bar or rail which may be gripped by means of a gripping element of the carrier. To sum up, the docking system may improve positioning accuracy and may stabilize the carrier at the target point, whereby movements of the cleaning device and possible other operational devices may also be more accurate. The mechanical docking may comprise any kind of mechanical elements interlinking the carrier and the target point with each other.

According to an embodiment, the apparatus is configured to generate one or more virtual movement paths and is configured to drive the carrier along them. The movement paths may be generated on-line in the control unit in response to received data on surrounding and current position of the apparatus together with data on position of one or more target points. The generated movement path may be of single-use type, whereby a new movement path may be generated for each transfer movement. In other words, the generated movement path may be transient. Alternatively, the generated virtual movement paths may be stored and re-used for several transfer drives.

According to an embodiment, the apparatus is provided with 3D movement paths. Thus, the route to drive by the apparatus does not need to be levelled but may comprise vertical differences. In other words, the

apparatus may be driven not only on flat or planar surface but also along inclined portions.

According to an embodiment, the apparatus is configured to clean two adjacent smelt spouts simultaneously. Then the apparatus comprises two cleaning units arranged on the carrier. Further, at least some target points of the working area are located between the adjacent smelt spouts. The control unit positions the carrier and the cleaning units at the adjacent two smelt spouts for executing the cleaning and possible other work tasks.

According to an embodiment, the apparatus comprises transfer means for moving the at least one cleaning unit away from the carrier at the smelt spout. Thus, the carrier is configured to serve as a transport platform for one or several cleaning units. In this embodiment, the target point i.e. structures at the smelt spout comprise receiving elements for receiving the cleaning unit from the carrier. Alternatively, the cleaning unit comprises a support structure by means of which it is supported on the driving surface of the service platform. The cleaning unit may comprise support legs, for example. The same principle may also be implemented for other operational devices, whereby the carrier may transfer the devices to desired target points, may pick up the devices after they have executed their work cycle, and may transfer the devices to next task points or to a storage place for waiting forthcoming tasks. The means for moving the operational devices on and away from the carrier may comprise rails, slide elements, telescopic support bars or transversally moving carriages which are operated by means of one or more actuators. The actuator may be an electric motor arranged to move the operational device relative to the carrier. An advantage of this embodiment is that the same carrier may serve several cleaning units and other operational devices. Idle

time of the carrier may be avoided since the carrier is not occupied for the duration of the work cycle of the operational device but may execute transfer drive for other operational devices. Thereby transfer capacity of the carrier may be utilized better. In case each of the smelt spouts are provided with dedicated cleaning units or other operational devices, the disclosed carrier may be utilized for transferring the operational devices to service and repair.

According to an embodiment, the apparatus is electrically operable. Then the carrier comprises at least one electrical drive motor. The wheels or tracks of the carrier may be provided with electrical hub motors, for example. Further, the carrier comprises at least one on-board electric energy storage for storing needed operational power at least for the transfer drive of the carrier. An advantage of the on-board energy storage is that the carrier may be driven independently inside the working area.

According to an embodiment, the carrier is a battery operated device and the working area of the apparatus comprises one or more charging points for charging on-board batteries of the carrier. The charging point may be located at the smelt spout whereby the charging may be executed during the cleaning process when the carrier is immobile. Then the target point is provided with electrical connection to an electric network. Further, the network may also provide the cleaning unit on the carrier with the needed operational power. An advantage of this embodiment is that the idle time of the carrier at the target point may be utilized for the charging.

According to an embodiment, the apparatus is electrically operable and the carrier is connected to an electric network by means of at least one supply cable. The carrier may comprise at least one cable reel for the

electric supply cable. However, in connection with the supply cable may be at least one fluid tube for pressurized air or water, or alternatively, the carrier may comprise at least one additional cable reel for a separate fluid tube. An advantage of the electric supply cable is that the carrier may be fully energized all the time. The cable reel system provides the carrier with free driving despite the continuous connection to the electric network. The connection through the fluid tube to pressurized water and air systems allows the cleaning unit to utilize effective water jets and air blowing in the cleaning processes.

According to an embodiment, the carrier is provided with at least one on-board storage device for storing several tools. An advantage of the tool storage is that all the needed tools are always available. When the apparatus is provided with a large number of tools, the apparatus may carry out versatile operations at the target points. Since the tools are carried by the carrier no space needs to be reserved at the smelt spout for storing the tools. Further, the on-board tool storage increases independence of the apparatus.

According to an embodiment, the carrier may comprise one or more tool racks for storing tools on-board the carrier. The tool rack may be a mechanical support structure comprising tool holders or corresponding elements on which the tools may be supported. The tool rack may be arranged to receive the tools parallel relative to the driving direction of the carrier allowing thereby storing of tools having great length.

According to an embodiment, the carrier comprises one or more tool magazines inside which are several movable storage places for the tools. The tool magazine may comprise a revolving piece an outer periphery of which comprises tool spaces. Alternatively, the magazine may be a linearly moving piece provided with suitable tool

spaces. The magazine may be indexed by means of an indexing actuator so that a robot or manipulator arranged on the carrier may grip the desired tool and may return used tools into empty spaces of the magazine. An advantage of the tool magazine is that a large number of tools may be stored on the carrier in a compact manner.

According to an embodiment, the on-board tool storage device may comprise several different type of tools and may also comprise spare tools for at least some of them. The tool storage may comprise at least one rodding tool, at least one measuring instrument, at least one sampling tool, and at least one fluid spraying jet, such as a water or air nozzle. Tools for mechanical cleaning may comprise a brush, a rod or a chisel. Further, the mechanical cleaning may be made more effective by vibrating or hammering the tool during the cleaning. Thus, in connection with the tool may be an impact device or vibrator.

According to an embodiment, the apparatus is configured to open and close hatches and lids at the target point. For the purpose, the apparatus may be equipped with a suitable tool, such as a gripping tool, for handling different type of the hatches and lids. Typically the smelt spout is protected by a hood structure, which comprises a service lid allowing access to the smelt spout. The hinged lid may comprise a hatch for closing it. However, there may also be other kind of service and inspection lids, which may be opened and closed by the disclosed apparatus.

According to an embodiment, the apparatus is configured to execute mechanical cleaning of the smelt spout. Thus, the apparatus utilizes the motorized cleaning unit to perform the rodding. In order to reduce wear of the smelt spout, the apparatus may be programmed not to touch the spout surface.

According to an embodiment, the apparatus is configured to execute inspection measures at the target point. The apparatus may be provided with a camera system for providing visual data for operators of the recovery boiler. Further, the apparatus may be provided with one or more measuring devices or sensors by means of which operation of selected items at the target point may be monitored. The camera and the sensing means may be changeable tools and may be stored to the tool storage on the carrier. Then a robot or manipulator arranged on the carrier may select a suitable inspection tool and may position it to a suitable place for monitoring operation and performance of the selected devices of the recovery boiler.

According to an embodiment, the apparatus is configured to take smelt samples and to transfer them to a sample station for further inspection. The sample station may be located at the working area of the apparatus. The samples can be taken by means of a sample cup or corresponding sample tool. The samples may be taken automatically on a scheduled basis or when especially required.

According to an embodiment, the apparatus is configured to clean surroundings of the smelt spout and enclosing hood structure. Also the service platform may be cleaned by means of air, steam and water jets, for example. Thus, the apparatus may be provided with water and air nozzles as the operational tools.

According to an embodiment, the apparatus is provided with a plugging tool for plugging the smelt spout when needed. Flow of smelt may be prevented in emergency situations, for example.

According to an embodiment, the carrier is intended especially for transport purposes. Then the apparatus may transfer stand-alone operational devices inside the working area. The carrier may also transfer

spare parts, mounting tools and other components to desired target points in order to facilitate service and repair measures. The system may comprise one or more carriers, which are specialized only for transferring selected items inside the working area and are not provided with any fixedly mounted cleaning unit. Further, two or more transport carriers may be arranged to co-operate when executing the operational tasks. It may also possible that the transport carrier tows a disabled carrier away from the working area.

According to an embodiment, the apparatus is configured to assist in starting procedure of the recovery boiler. The apparatus may be configured to execute starting and stopping of start-up burners, and the apparatus may also supervise the entire starting process.

According to an embodiment, the apparatus is configured to clean a steam shattering device or corresponding smelt flow shattering device. The cleaning may be performed using mechanical tools or by directing a steam, water or air jet to the device. The mentioned shattering device is typically located at an end portion of the smelt spout.

According to an embodiment, the apparatus is configured to clean primary air level air nozzles of the recovery boiler. The air nozzles are located above the smelt spouts. The cleaning of the nozzles may be performed by means of fluid jets.

According to an embodiment, the apparatus is configured to execute all operative work tasks that are conventionally performed manually by operators at the smelt spout area of the recovery boiler.

According to an embodiment, the work area of the disclosed system comprises at least the smelt spout area and the service platform adjacent the smelt spouts. However, one or more target points of the apparatus may be located external to the smelt spout area and the service

platform, whereby the work area of the apparatus may be larger than the service area of the smelt spouts. This way it is possible to allow the apparatus to move out of the service platform to execute a special task at a distance from the normal smelt spout area. The work area may thereby comprise the basic work area and one or more additional work areas. The target points locating at the additional work areas may comprise a sample receiving station, a battery charging station or a cleaning unit service station, for example.

The above disclosed embodiments and features may be combined in order to form suitable solutions that are needed.

Brief description of the figures

Some embodiments are described in more detail in the accompanying drawings, in which

Figure 1 shows schematically a lower part of a recovery boiler and a smelt spout area wherein a cleaning apparatus is positioned at one smelt spout,

Figure 2 shows schematically a smelt spout attached to a wall of a conventional chemical recovery boiler,

Figure 3 is a schematic side view of a wheeled apparatus capable of being driven on a service platform of the recovery boiler,

Figure 4 is a schematic side view of an alternative apparatus provided with tracks for driving it on a driving surface,

Figure 5 is schematic front view of an apparatus carrying an industrial robot and a tool magazine on an upper surface of a wheeled carrier,

Figure 6 is a schematic front view of an apparatus comprising moving members on an upper surface of a carrier for transferring operational devices on and away from the carrier,

Figure 7 is a schematic top view showing some driving paths of an apparatus inside a working area adjacent a recovery boiler,

Figure 8 is a schematic top view showing a drive path of a transfer carrier inside a working area adjacent a recovery boiler.

For the sake of clarity, the figures show some embodiments of the disclosed solution in a simplified manner. In the figures, like reference numerals identify like elements.

Detailed description of some embodiments

Figure 1 discloses a lower part of a recovery boiler 1. Walls 2 of the recovery boiler 1 are typically formed by water-cooled tubes, which are shaped to provide an opening 3 above a bottom 4 of a furnace portion 5 of the boiler 1. Extending through the opening 3 is a smelt spout 6. The boiler 1 may comprise several smelt spouts, the number of the spouts may be 2, 3, 4, 5 or 6, for example. The portion of the smelt spout 6 extending outside the boiler 1 may be surrounded by an enclosure or hood to prevent liquid and smelt splashes and exhaust gases from being discharged into the surrounding environment. The lower end of the smelt spout 6 is disposed within an opening of a dissolving tank 7, which is located underneath the smelt spout 6. The dissolving tank 7 receives the smelt from the spout and inside the tank 7 the smelt is dissolved in liquid forming green liquor.

At a smelt spout area 8 is a service platform 9 for facilitating cleaning of the smelt spout and other service operations. On an upper surface of the service platform 9 may be arranged a wheeled apparatus 10, which may be driven between the several smelt spouts 6 and other target positions. The apparatus 10 comprises a carrier 11 and several wheels 12. The carrier 11 is equipped with a motorized cleaning unit 13, which may be an industrial

robot, for example. The cleaning unit 13 may clean the opening 3 and the smelt spout 6 by moving mechanical cleaning tools in accordance with pre-programmed cleaning movements. The cleaning unit 13 may be any kind of moving apparatus which may generate the needed cleaning movement and may operate automatically or under remote control. Further, the cleaning unit 13 may be arranged to clean also different type of air nozzles and openings 14 of the recovery boiler 1.

Figure 2 discloses that the smelt spout 6 is enveloped by a hood 15 comprising an openable lid 16, which may be locked by means of a hatch 17. The cleaning unit needs to open the hatch 17 and the lid 16 so that the cleaning measures may be executed through a service opening 18. Very hot, fluid smelt runs from the bottom 4 of the furnace portion 5 of the boiler 1 via the opening 3 to the smelt spout 6. The smelt flows along a bottom 19 of the groove-like spout 6 and falls from the free end of the spout 6 into the dissolving tank 7. In order to break up the fluid smelt into smaller drops before it reaches the dissolving tank 7, jets of steam may be directed to shatter the smelt flow using shatter jet nozzle or shattering device 20. When the apparatus comprising the cleaning unit is positioned at the smelt spout, it may not only clean the spout 6 and the opening 3, but may also clean surfaces of the hood 15 and the lid. The cleaning unit may also clean the shattering device 20 and may plug the opening 3 by means of a plugging element. Further, the cleaning unit may take samples from the smelt flow by means of a sample cup.

Figure 3 discloses an apparatus 10 comprising a carrier 11 provided with several wheels 12. An upper surface of the service platform 9 or other floor surface serves as a driving surface 21 for the apparatus. The carrier 11 may comprise three, four or more wheels 12 and at least some of them are steerable allowing the carrier

to be moved freely on the driving surface 21. The carrier 11 comprises at least one drive motor 22 and suitable number of steering actuators 23. The drive motor 22 may be electric and may be powered by means of a battery 24. The apparatus 10 may comprise scanners S for providing a control unit CU-1 with positioning information. Positioning computations, path planning and produce of steering instructions may be executed in the on-board control unit CU-1, or in assistance with one or more external control units CU-2. An upper surface of the carrier 11 may serve as a load carrying platform on which a cleaning unit 13 may be supported. Operation of the cleaning unit 13 may be controlled by means of a dedicated control unit CU-3. The cleaning unit 13 may comprise a base 25, which may be turned R relative to the carrier 11. A first arm 26 is connected to the base 25 by means of a first joint 27 and a second arm 28 is connected to an outer end of the first arm 26 by means of a second joint 29. The arms 26, 28 can be turned T in a versatile manner around the joints 27, 29. A distal end of the second arm 28 comprises a tool holder 30 for mounting different tools to the cleaning unit 13. The cleaning unit may be an industrial robot and the number of the arms and degrees of freedom may be greater as disclosed in Figure 3.

Figure 3 further discloses that the carrier 11 may comprise a tool rack 31 for storing several tools 32.

In Figure 4 the carrier 11 of the apparatus 10 comprises crawler tracks 33, which are supported against the driving surface 21. The apparatus 10 is electrically operable and is connected to external electric network through a supply cable 34, which may be controlled by means of cable reel 35. On the carrier 11 are two cleaning units 13a, 13b, so that the apparatus 10 can clean two smelt spouts 6 simultaneously. Then a target point TP for positioning the apparatus 10 is located between the two smelt spouts 6. At the target point TP may be an

artificial reference marking 36, which may be detected by means of a rotating scanning device S. At the smelt spouts 6 may be reference markings 37 for calibrating positions of the cleaning devices 13a, 13b before initiating their cleaning cycles. The cleaning units may comprise computer vision systems for detecting the reference markings 37.

Figure 5 discloses a wheeled carrier 11 on which is an industrial robot serving as the cleaning unit 13. The carrier 11 also comprises a rotating tool magazine 38 provided with spaces 39 inside which tools 32 may be stored. The carrier 11 may comprise a detecting device 40 for detecting reference lines 41 or markings arranged on the driving surface 21, or alternatively to wall surfaces. Another possible positioning system comprises scanners S which may scan surrounding surfaces 42 of the apparatus whereby the gathered data on surface topography 43 and features may be used to define positioning of the apparatus. Furthermore, the positioning may be based on receiving electronic signals from base stations or other transmitters 44 by means of receiving devices R.

Figure 6 discloses that the cleaning unit 13 may be moved transversally from the carrier 11 to a support station 45. This way the cleaning unit 13 may be left at the target position TP and the carrier 11 may continue driving to other target points. On the carrier 11 may be a sliding table 46, rails, guide bars, or corresponding transfer elements for moving the cleaning unit 13 in transverse direction C. The sliding table 46 may be moved by means of an electric motor 47, for example. The support station 45 or receiving station provides needed mechanical support and electric power for the cleaning device 13.

Figure 7 discloses a basic work area 48, which covers at least the smelt spout area and the service platform. However, there may be an additional work area 49 outside the service platform. The apparatus 10 may be driven freely inside the work areas 48 and 49. The

apparatus 10 may have linear drive path sections 50, curved drive path sections 51 and angular drive path sections 52. The apparatus 10 may generate the drive path by itself. All the smelt spouts 6 are possible target points for the apparatus 10. Additional target points for the positioning may be a charging station 53, a smelt sample receiving station 54, and one or more inspection points 55, for example.

In Figure 8 it is disclosed a drive path of a transfer apparatus 10 inside the working area 48. The transfer apparatus comprises a freely movable carrier 11 on which are load carrying elements 56 for carrying separate cleaning devices 13, inspection devices 57, components 58 and other needed devices and items between target points. The apparatus 10 may also transfer the load to a storage or service area 59.

Figure 8 further discloses that the apparatus 10 may detect a physical obstacle 60 at the work area 48 and may dodge D it by executing suitable steering movements.

The drawings and the related description are only intended to illustrate the idea of the invention. In its details, the invention may vary within the scope of the claims.

Claims

1. An apparatus for cleaning smelt spouts (6) of a recovery boiler (1), the apparatus (10) comprises:

at least one cleaning unit (13) comprising motorized means for moving a cleaning tool (32) connectable to the cleaning unit (13);

transfer means for moving the cleaning unit (13) to a location of the smelt spout (6) to be cleaned; and

at least one control unit (CU) for controlling work cycle of the apparatus (10);

characterized in that

the transfer means comprise a self-propelling carrier (11) provided with several moving elements (12, 33) supportable on a driving surface (21) at the recovery boiler (1);

at least some of the mentioned moving elements (12, 33) are steerable, whereby the carrier (11) is freely movable on the driving surface (21); and

the control unit (CU) is configured to determine a movement path for the transfer drive of the carrier (11) and is configured to navigate the carrier (11) along the determined movement path.

2. The apparatus as claimed in claim 1, characterized in that

the carrier (11) comprises several wheels (12) supportable against the driving surface (21), whereby the apparatus (10) is a wheeled vehicle.

3. The apparatus as claimed in claim 1 or 2, characterized in that

the control unit (CU) is provided with data on at least one target point (TP);

the apparatus (10) comprises a positioning system for providing the control unit (CU) data on current

position and direction of the carrier (11) relative to position and direction of the target point (TP); and

the control unit (CU) is configured to generate a virtual movement path for the transfer drive of the carrier (11) and is configured to generate steering commands for automatically steering the carrier (11) along the generated virtual movement path to the target point (TP).

4. The apparatus as claimed in any one of the preceding claims 1 - 3, characterized in that

the apparatus (10) comprises a positioning system provided with at least one scanning device (S) for scanning surroundings of the apparatus (10);

the control unit (CU) is configured to determine the current position and direction of the apparatus (10) in a coordinate system in response to the generated scanning data received from the scanning device (S); and

the control unit (CU) is provided with position and direction data on at least one target point (TP) and is configured to generate navigation instructions towards the target point (TP).

5. The apparatus as claimed in claim 4, characterized in that

the control unit (CU) is provided with an environmental 3D map of the working area (48) of the apparatus (10) together with position data on the predetermined target points (TP);

the control unit (CU) is configured to generate 3D view of the surroundings of the apparatus (10) during the transfer drive in response to the scanning data; and

the control unit (CU) is configured to compare the current 3D view to the 3D map for determining the current position and direction of the apparatus (10) relative to the target point (TP).

6. The apparatus as claimed in any one of the preceding claims 1 - 4, characterized in that

the apparatus (10) comprises a positioning system provided with at least one detecting device (S, R, 40) for detecting reference markings (36, 44, 41) at reach of the apparatus (10); and

the control unit (CU) is configured to navigate the carrier (11) in response to the detected reference markings (36, 41).

7. The apparatus as claimed in any one of the preceding claims 1 - 6, characterized in that

the apparatus (10) comprises two cleaning units (13a, 13b) arranged on the carrier (11);

the control unit (CU) is configured to position the cleaning units (13a, 13b) at adjacent two smelt spouts (6); and

the apparatus (10) is configured to clean the two adjacent smelt spouts (6) simultaneously.

8. The apparatus as claimed in any one of the preceding claims 1 - 6, characterized in that

the apparatus (10) comprises transfer means (46) for moving the at least one cleaning unit (13) away from the carrier (11) at the smelt spout (6).

9. The apparatus as claimed in any one of the preceding claims 1 - 8, characterized in that

the carrier (11) comprises at least one electrical drive motor (22); and

the carrier (11) comprises at least one on-board electric energy storage (24) for storing needed operational power at least for the transfer movement of the carrier (11).

10. The apparatus as claimed in any one of the preceding claims 1 - 9, characterized in that

the carrier (11) is provided with at least one on-board storage device (31, 38) for storing several tools (32).

11. An arrangement in a recovery boiler (1), wherein the arrangement comprises:

several smelt spouts (6) of the recovery boiler (1);

a service platform (9), which is located adjacent the smelt spouts (6) and defines at least partly a work area (48);

at least one cleaning unit (13) comprising motorized means for moving a cleaning tool (32) connectable to the cleaning unit (13);

transfer means for moving the cleaning unit (13) inside the work area (48) to pre-defined target points (TP) for cleaning the smelt spouts (6) by means of the cleaning unit (13); and

at least one control unit (CU) for controlling work cycles of the cleaning unit (13) and the transfer means;

characterized in that

the transfer means comprise a carrier (11) provided with several moving elements (12, 33) supported on the service platform (9) serving as a driving surface (21) for the carrier (11); and

the control unit (CU) is configured to navigate the carrier (11) freely inside the work area (48) between the pre-determined target points (TP).

12. The arrangement as claimed in claim 11, characterized in that

20175563 PRH 16-06-2017

the work area (48) of the arrangement comprises at least one additional target point (53, 54, 55) location of which is separate from the smelt spouts (6); and

the control unit (CU) is configured to navigate the carrier (11) to the additional target point and to execute therein a work cycle other than the cleaning of the smelt spouts (6).

13. An arrangement in a recovery boiler (1), wherein the arrangement comprises:

a service platform (9) defining at least partly a work area (48);

at least one transfer device movable inside the work area (48) to several target points (TP);

at least one operating device (13, 57) supported to the transfer device; and

at least one control unit (CU) for controlling at least work cycle of the transfer device;

characterized in that

the transfer device comprises a carrier (11) provided with several moving elements (12, 33) supported on the service platform (9) serving as a driving surface (21) for the carrier (11); and

the control unit (CU) is configured to navigate the carrier (11) freely inside the work area (48) between the target points (TP).

14. A method of cleaning smelt spouts (6) of a recovery boiler (1),

the method comprising:

transferring at least one cleaning apparatus (13) to pre-defined target points (TP) for cleaning the smelt spouts (6);

cleaning the smelt spouts (6) by means of the cleaning apparatus (10) comprising at least one cleaning

unit (13) provided with motorized means for moving a cleaning tool (32); and

controlling the transferring and cleaning work cycles automatically under control of at least one control unit (CU);

characterized in that the method further comprises:

driving the cleaning apparatus (10) freely on a driving surface (21); and

navigating the cleaning apparatus (10) along at least one movement path defined by the control unit (CU).

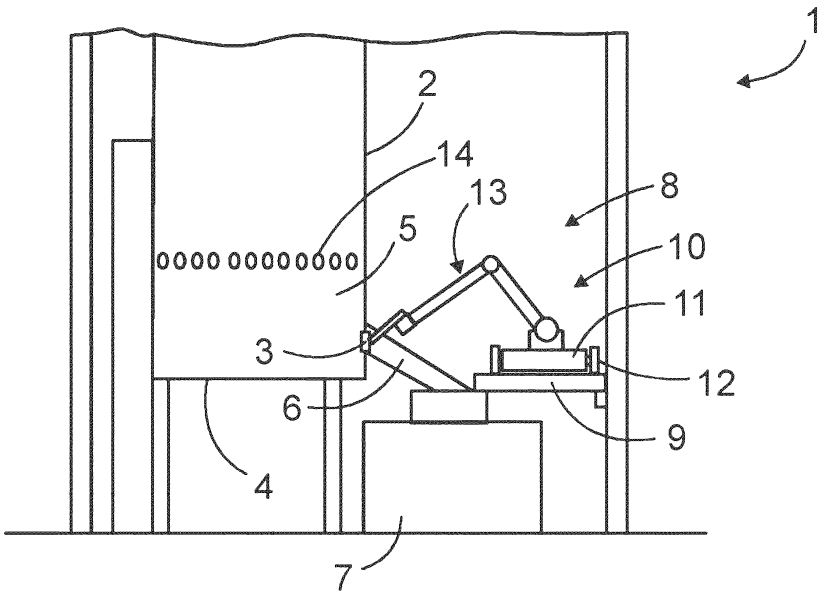


Fig. 1

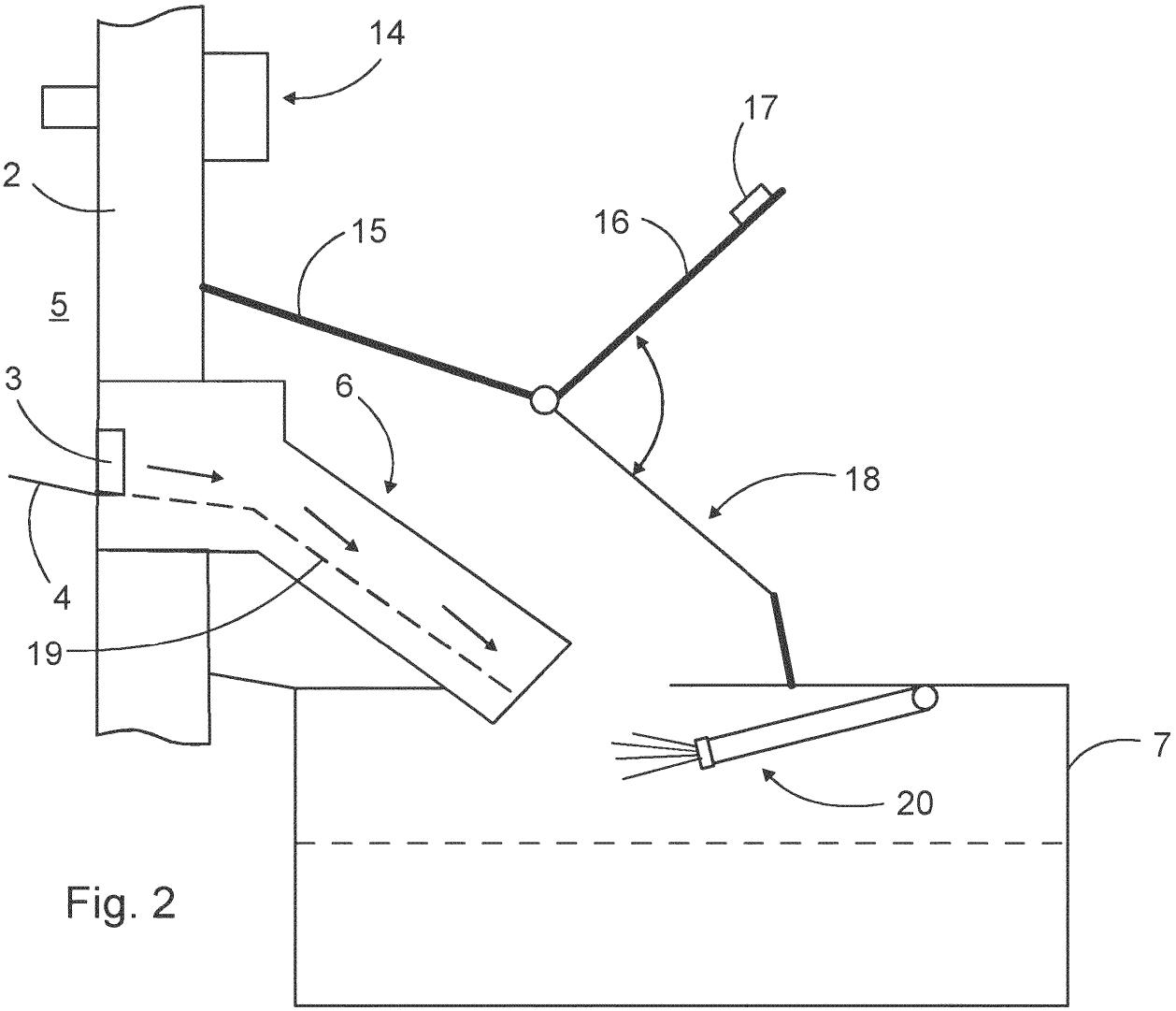


Fig. 2

20175563 PRH 16-06-2017

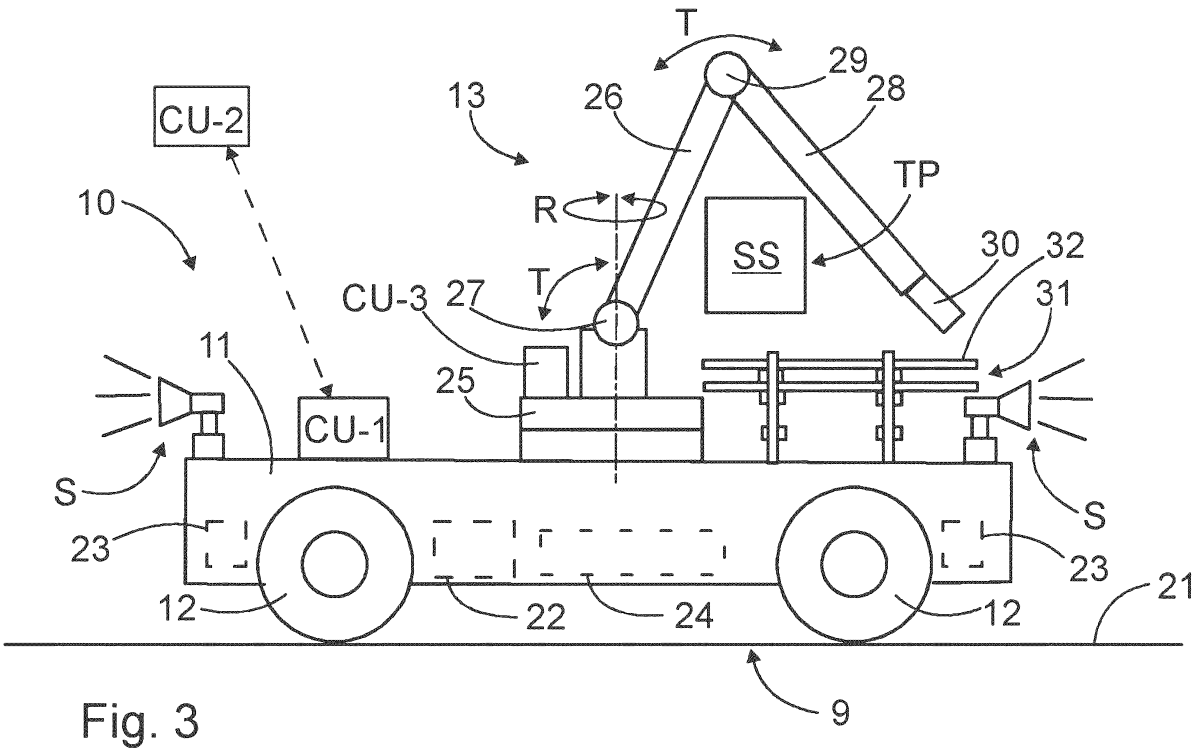


Fig. 3

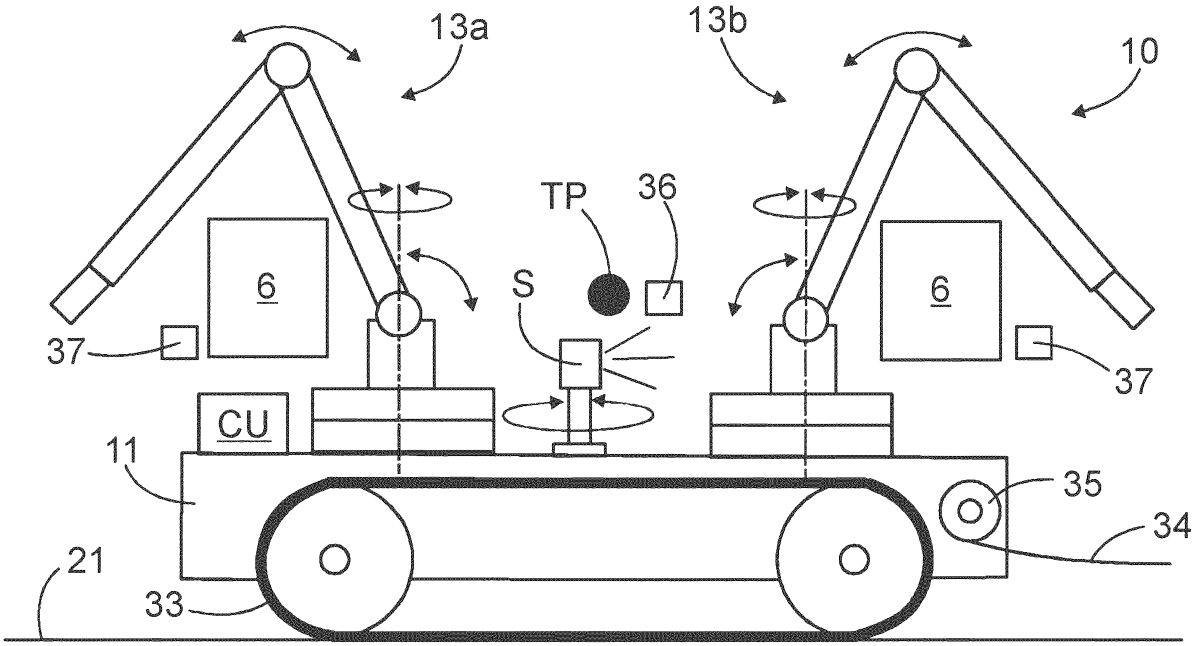


Fig. 4

20175563 PRH 16-06-2017

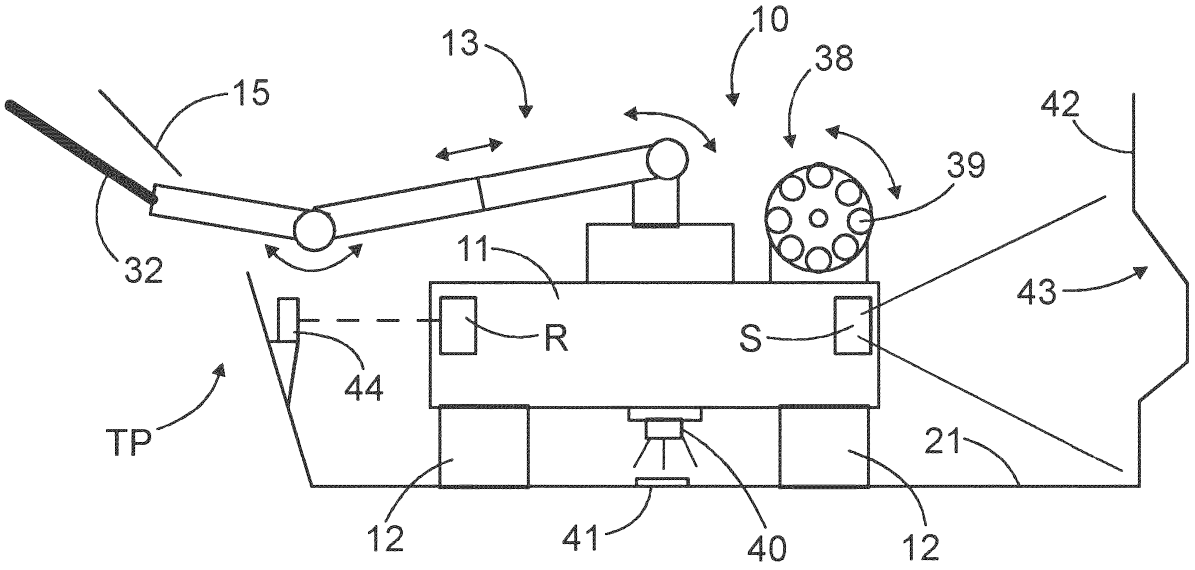


Fig. 5

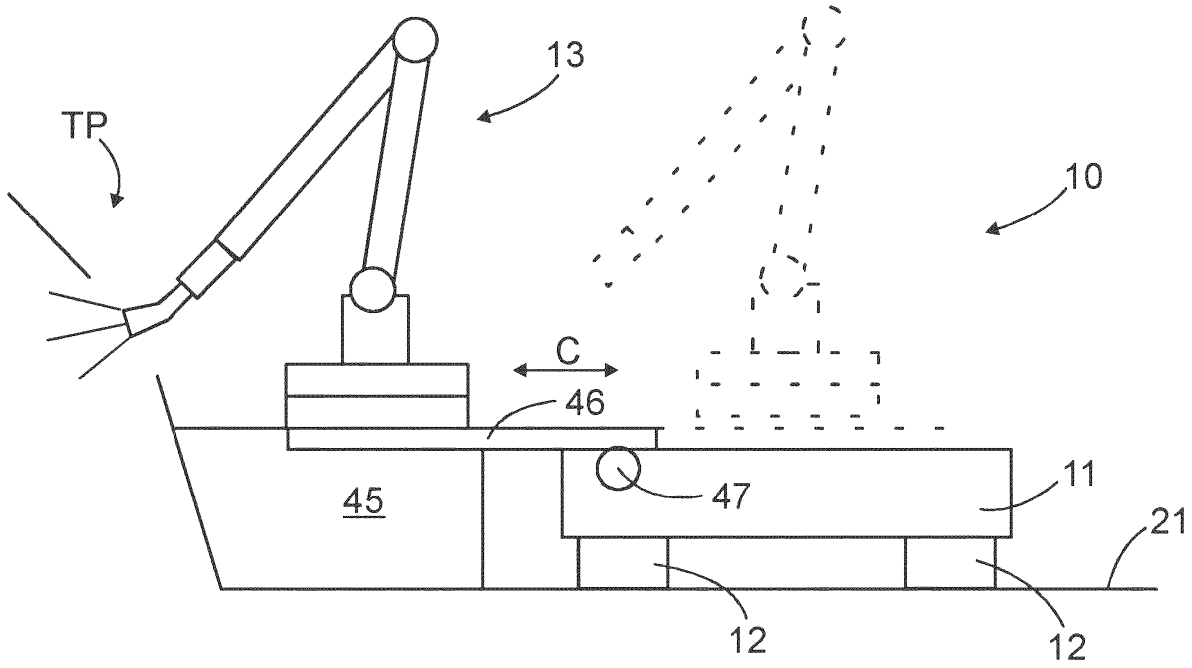


Fig. 6

20175563 PRH 16 -06- 2017

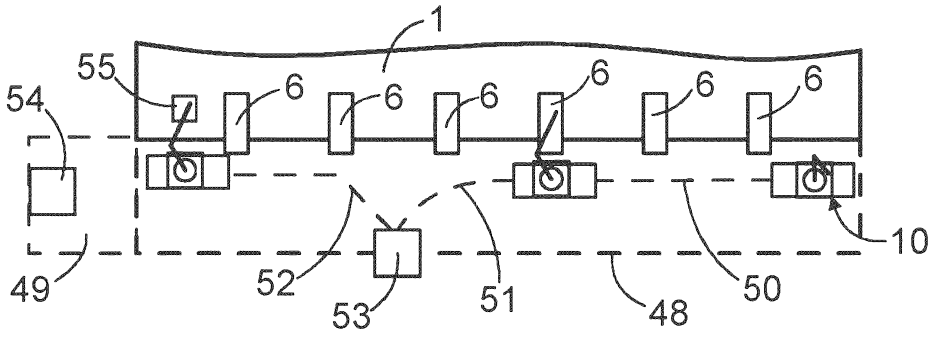


Fig. 7

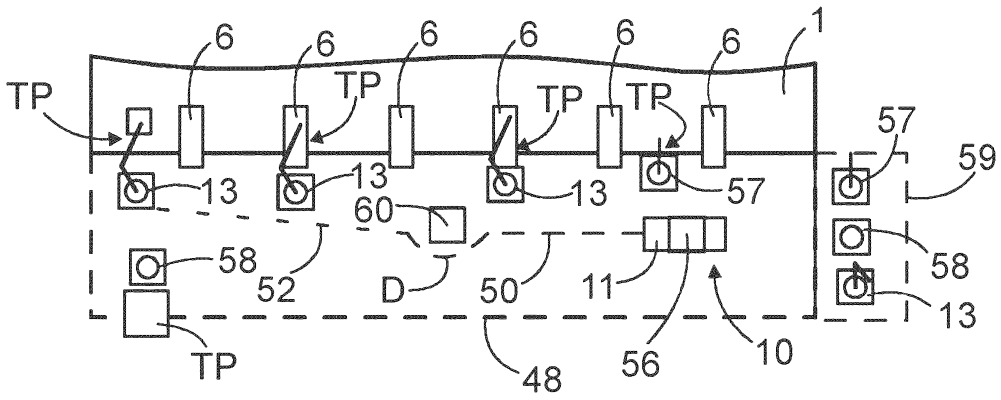


Fig. 8

20175563 PRH 16 -06- 2017