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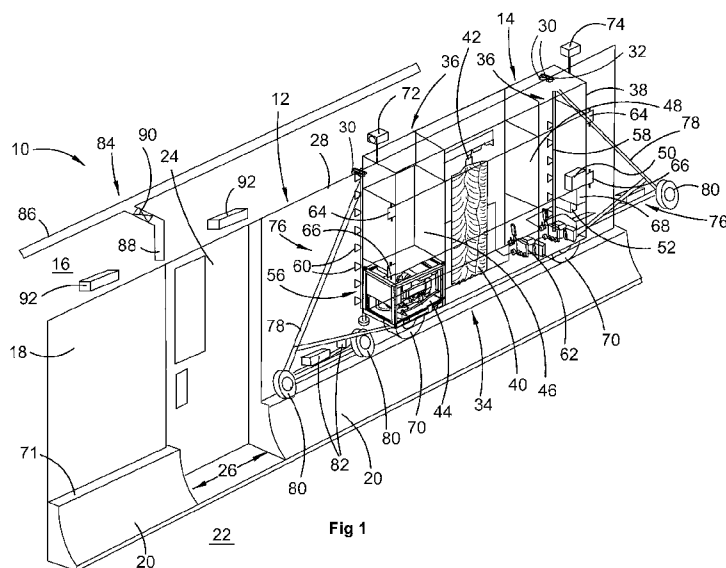


Fig 1

(57) Abstract: An autonomous tunnel cleaning system (ATCS) (10) has a guidance system (12) and a cleaning apparatus (14). The guidance system (12) is capable of guiding the cleaning apparatus (14) along at least a portion of a tunnel (16). The cleaning apparatus is capable of autonomously travelling along the tunnel (16) under guidance of the guidance system (12). The cleaning apparatus (14) cleans a length of the tunnel (16) while it travels along the tunnel. The cleaning apparatus (14) has a brushing member (34) and a fluid delivery system (36). The fluid delivery system (36) includes tanks (46, 48) and spray manifolds (56) and (58). The fluid delivery system (36) operates to deliver fluid onto the wall (18) in advance of and/or trailing the brushing member (34). A refilling system (84) enables automatic refilling of tanks (46), and (48) as the ATCS (10) travels along the tunnel.

AUTONOMOUS TUNNEL CLEANING SYSTEMTechnical Field

- 5 An autonomous tunnel washing system is disclosed. The system is suitable for cleaning of a vehicle tunnel while the tunnel is open to traffic.

Background Art

- 10 Motor vehicle tunnels are usually provided with extensive air replenishment systems that act to exchange air from within the tunnel with fresh air. Notwithstanding the often rapid replacement of air, walls of the tunnel are quickly blackened by particles carried in motor vehicle exhaust gases. From time to time it is necessary to clean the walls of the tunnel to remove the particles. Typically this is done manually and requires the
15 shutting down of one or more vehicle lanes or the entire tunnel to meet prescribed safety requirements for workers in the tunnel.

Summary of the Disclosure

- 20 In broad terms the general idea of the disclosed autonomous tunnel cleaning system is to provide a system that enables tunnel cleaning to be performed without the need of an on-board human operator. This facilitates cleaning without disrupting traffic flow through the tunnel.
- 25 In a first aspect there is disclosed an autonomous surface cleaning system comprising:
a guidance system; and
a cleaning apparatus;
wherein the guidance system is capable of guiding the cleaning apparatus
along at least a portion of the tunnel and the cleaning apparatus is capable of
30 autonomously traveling along the tunnel under guidance of the guidance system and cleaning a length of the tunnel while it travels along the tunnel.

In one embodiment the guidance system comprises at least one track extending along the tunnel.

35

In one embodiment the at least one track is supported on a wall of the tunnel.

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In one embodiment the at least one track is supported on the tunnel in a manner to suspend the cleaning apparatus.

5 In one embodiment the at least one track comprises a first track supported on a wall of the tunnel and a second track on a barrier disposed along the tunnel.

In one embodiment the second track comprises: (a) an upper horizontal surface or edge of the barrier or (b) a rail that is supported on or in the barrier.

10 In one embodiment the autonomous surface cleaning system comprises a gap straddling system coupled to the cleaning apparatus to enable the cleaning apparatus to a gap along the length of the tunnel.

15 In one embodiment the gap straddling system comprises two straddling mechanism, one on each side of the cleaning apparatus.

In one embodiment each straddling mechanism comprises a straddle frame and two spaced contact members supported on the straddle frame.

20 In one embodiment the contact members comprise guide wheels wherein the guide wheels on each straddle frame are spaced by a distance sufficient to so that each guide wheel can be in contact with a surface on opposite sides of the gap.

25 In one embodiment the autonomous surface cleaning system comprises a powered traction system coupled to the cleaning apparatus and capable of propelling the cleaning apparatus along the tunnel.

In one embodiment the powered traction system comprises at least one driven wheel.

30 In one embodiment the at least one driven wheel is arranged to engage a road in the tunnel. Alternately or additionally the at least one driven wheel may be arranged to engage at least one track.

35 In one embodiment the autonomous surface cleaning system comprises at least one brushing member capable of physically brushing a surface of the tunnel being cleaned when the cleaning apparatus travels along the tunnel.

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In one embodiment the at least one brushing member is powered to move relative to a support frame of the cleaning apparatus.

5 In one embodiment the at least one brushing member is powered to rotate as it contacts the surface being cleaned.

In one embodiment the autonomous surface cleaning system comprises a cleaning fluid delivery system arranged to deliver cleaning fluid onto the surface being cleaned.

10 In one embodiment the cleaning fluid delivery system comprises at least one fluid spray manifold arranged to spray cleaning fluid onto the length of the tunnel as the cleaning apparatus travels along the length of the tunnel.

15 In one embodiment the cleaning fluid delivery system comprises first and second spray manifolds arranged on opposite sides of the brushing member wherein the spray manifolds are operable to spray cleaning fluid onto the length of the tunnel either: (a) in advance of the brushing member; (b) trailing the brushing member; or (c) both in advance of and trailing the cleaning apparatus.

20 In one embodiment the cleaning fluid delivery system is arranged to deliver more than one type of cleaning fluid onto the surface being cleaned.

In one embodiment the cleaning fluid delivery system comprises at least one tank for holding a volume of a first cleaning fluid.

25

In one embodiment the cleaning fluid delivery system comprises at least one tank for holding a volume of a second cleaning fluid.

30 In one embodiment the cleaning fluid delivery system is arranged to deliver the second fluid on the surface being cleaned wall either (a) separately to the first cleaning fluid; or (b) as a mixture with the first cleaning fluid.

35 In one embodiment the autonomous surface cleaning comprises a cleaning fluid supply extending along the length of the tunnel and arranged to fill at least the tank or tanks for holding the first cleaning fluid at one or more spaced refill locations along the track.

In one embodiment the cleaning fluid supply may be provided with a plurality of

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disposed at the one or more refill locations and being arranged to open automatically when the at least one tank for holding a volume of a first cleaning is positioned at a corresponding refill location.

- 5 In one embodiment the autonomous tunnel cleaning system is arranged such that travel speed of the cleaning apparatus: progressively reduces from a cleaning speed as the cleaning apparatus approaches a refill location to zero when it reaches the refill location; and, after refilling of the tank or tanks for holding the first cleaning fluid, progressive increase from zero toward the cleaning speed.

10

In one embodiment the autonomous surface cleaning system comprises an on-board power pack capable of providing operational power to the cleaning apparatus.

- 15 In an alternate embodiment the autonomous tunnel cleaning system comprises an electrical supply bus extending along the guide and support system and arranged to provide electrical power to the cleaning apparatus. In this embodiment the cleaning apparatus may be provided with an electrical brush arranged to contact the bus. In one example the electrical brush may be supported on a pantograph and biased into contact with the bus.

20

In one embodiment the autonomous surface cleaning system comprises an on-board controller capable of controlling operation of the cleaning apparatus in response to signals received from on-board sensors and/or signals sent from a remote location. .

25 Brief Description of the Drawings

Notwithstanding any other forms which may fall within the scope of the system as set forth in the Summary, specific embodiments will now be described, by way of example only, with reference to the accompanying drawings in which:

30

Figure 1 is a perspective schematic representation of a first embodiment of the disclosed autonomous tunnel cleaning system;

Figure 2 is a front elevation of the system depicted in Figure 1;

Figure 3 is a top elevation of the system shown in Figures 1 and 2;

- 35 Figure 4 is a left hand side elevation of the system shown in Figures 1 – 3;

Figure 5 is a right hand side elevation of the system shown in Figure 1;

Figure 6 is a perspective schematic representation of second embodiment of the

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disclosed autonomous tunnel cleaning system;

Figure 7 is a front elevation of the system depicted in Figure 6;

Figure 8 is a top elevation of the system shown in Figure 6;

Figure 9 is a left hand side elevation of the system shown in Figure 6;

5 Figure 10 is a perspective schematic representation of third embodiment of the disclosed autonomous tunnel cleaning system;

Figure 11 is a front elevation of the system depicted in Figure 10;

Figure 12 is a top elevation of the system shown in Figure 10; and

Figure 13 is a left hand side elevation of the system shown in Figure 10.

10

Detailed Description of Preferred Embodiments

Figures 1 – 5 depict one embodiment of the disclosed autonomous tunnel cleaning system 10a (“ATCS”). The ATCS 10 comprises a guidance system 12 and a cleaning
15 apparatus 14. The guidance system 12 is capable of guiding the cleaning apparatus 14 along at least a portion of a tunnel 16. The cleaning apparatus is capable of autonomously travelling along the tunnel 16 under guidance of the guidance system 12. The cleaning apparatus 14 cleans a length of the tunnel 16 while it travels along the tunnel.

20

Figure 1 depicts a short length or section of the tunnel 16. The tunnel 16 has an upright side wall 18. Such a wall 18 will be on both sides of the tunnel 16. A traffic barrier or curbing 20 also extends along the tunnel adjacent the wall 18. This provides a barrier between the wall 18 and traffic which may be travelling on a road 22 in the
25 tunnel 16. An exit or access door 24 is provided in the wall 16. A gap 26 exists in the barrier 20 across the width of the door 24.

In this embodiment the guidance system 12 comprises a track 28 that is mounted or supported on the tunnel 16 and runs along and in this instance above the wall 18. The
30 track 28 is in the form of an “I” beam as seen most clearly in Figures 4 and 5. The guidance system 12 also comprises two pairs of guide wheels 30 which are attached to the cleaning apparatus 14 by respective arms 32. One guide wheel 30 in each pair is on opposite sides of the track 28. The guide wheels 30 are idle wheels and are not driven.

35

The cleaning apparatus 14 has a brushing member 34 and a fluid delivery system 36. These are supported by a frame 38. The brushing member 34 physically contacts the

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wall 18 as the ATCS 10 traverses the length of the tunnel 16. The fluid delivery system 36 operates to deliver fluid onto the wall 18 in advance of and/or trailing the brushing member 34. The fluid may be for example water, liquid detergent separate to the water, a mixture of water and detergent or combinations thereof. For example a
5 mixture of water and detergent can be delivered onto the wall 18 in advance of the brushing member 34 and water only delivered onto the wall 18 trailing the brushing member 34.

In this embodiment the brushing member 34 is in the form of a brush 40 having an
10 axial shaft 42 that is rotatably mounted within the frame 38. Torque is provided to the shaft 42 via an on-board power pack 44 to cause the brush 40 to rotate. Typically the brush 40 is formed with a plurality of fabric or synthetic material strands. When the shaft 42 is not rotated the strands simply hang down by action of gravity from the shaft 42 and do not reach or contact the wall 18. When the shaft 42 is rotated the centrifugal
15 force lifts the strands to extend out radially and thereby contact the wall 18.

The fluid delivery system 36 in this embodiment comprises two fluid tanks 46 and 48. The tanks 46 and 48 are on opposite sides of the brush 40. The tanks 46 and 48 may be interlinked by a conduit (not shown) so that fluid can be transferred between the
20 tanks 46 and 48. In this way for example filling of the tanks 46 and 48 can be achieved by delivering fluid into one of the tanks only. In another example depending on the specific configuration of the ATCS 10 if fluid is being delivered onto the wall 18 only say in advance of the brush 40 then fluid from a trailing tank can be delivered to the leading tank to thereby extend the operational travel of the ATCS 10 prior to refilling of
25 the fluid delivery system 36.

The fluid delivery system 36 also includes a subsidiary fluid tank 50. The subsidiary tank 50 may be located inside or outside of the tank 48. However the subsidiary tank 50 may be alternately placed in the tank 46 or indeed there may be two subsidiary
30 tanks, one for each of tanks 46 and 48. Each subsidiary tank 50 is provided to hold a supply of a different fluid to that contained in the main tanks 46 and 48. For example the tanks 46 and 48 may be filled with water while the subsidiary tank 50 may hold a supply of a specific cleaning fluid or detergent. A pump 52 is associated with the subsidiary tank 50 to control delivery of the cleaning fluid onto the wall 18.

35

In order to transfer fluid from the tanks 46, 48 and 50 onto the wall 18 the fluid delivery system is provided with a first manifold 56 and a second manifold 58. The manifold 56

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is associated with the tank 46 while the second manifold 58 is associated with the tank 48. The manifolds 56 and 58 are supported on the frame 38 and each has a plurality of nozzles 60 arranged to direct a spray of fluid onto the wall 18. A hydraulically driven pump 62 is also supported within the frame 38 and operable to pump fluid from the tanks 46 and 48 to the manifolds 56 and 58.

The cleaning chemical from the tank 50 can be delivered onto the wall 18 via the pump 52. The pump 52 can be arranged to pump the cleaning chemical either: directly onto the wall 18 via either one or both of the manifolds 56, 58; or into one or both of the tanks 56, 58 to be mixed with water prior to being sprayed onto the wall 18 by one or both of the manifolds 56, 58.

One possible operating scenario is that water is contained in both of the tanks 46 and 48 and a detergent is held within the tank 50. Detergent from the tank 50 is delivered to the leading manifold 56 or 58 depending on the direction of travel of the ATCS 10. Thus as the ATCS 10 travels along the tunnel 16 detergent and water are sprayed onto the wall 18 from the leading manifold 56/58 while rinsing water is sprayed from the trailing manifold.

High and low level liquid sensors 64 and 66 respectively are provided in each of the tanks 46 and 48. Signals from these sensors are sent to an on-board controller 68. The controller 68 includes a communication system enabling communication with a control room. In this way signals relating to the operational state of the ATCS 10 can be relayed to the control room and similarly control signals can be issued from an operator in the control room to the ATCS which are received by and acted upon by the on-board controller 68.

Although the ATCS 10 is guided by the guidance system 12, it is supported by two drive wheels 70. The drive wheels 70 are rotatably mounted on the frame 38 and are powered by the power pack 44. The wheels 70 run along an upper surface or edge 71 of the barrier 20.

The power pack 44 may be in the form of a combustion engine driving a hydraulic pump. Conveniently the combustion engine can be a diesel engine. An electric generator may also be provided within the power pack 44 or otherwise driven by the power pack 44 to provide electrical power to various systems and devices of the ATCS 10 such as the controller 68, sensors 64 and 66 and other sensors and electronic

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devices such as leading and trailing cameras 72 and 74 mounted at opposite ends of the frame 38.

5 The ATCS 10 is also provided with a gap straddling system 76. The system 76 enables the ATCS 10 to continue travelling along the barrier 20 notwithstanding the existence of gaps 26.

10 The gap straddling system 76 comprises, a straddle frame 78 attached to the main frame 38 and on opposite sides of the drive wheels 70. Each straddle frame 78 supports and at least one, although in this example two, contact members in the form of inline and spaced apart wheels 80.

15 The gap straddling system 76 is arranged so that prior to a drive wheel 70 reaching the gap 26 a wheel 80 will be on an opposite side of the gap 26 to thereby provide support of the cleaning apparatus 14 as it traverses the gap 26. In this way the gap straddling system 76 bears at least a part of the load of the weight of the cleaning apparatus 14 and ensures that this load is not transferred onto the track 28.

20 Gap proximity sensors 82 are provided at opposite ends of the gap straddling system 76. The sensors 82 sense the existence or approach of a gap 26. This information may be used by the controller 68 to reduce the speed of travel along the barrier 20 while the cleaning apparatus 14 traverses the gap 26.

25 In order to facilitate recharging of the tanks 46 and 48 the ATCS 10 is provided with a refilling system 84. The refilling system 84 includes a supply conduit 86 on each side of the tunnel 16. A number of discharge pipes 88 are plumbed into the supply conduit 86 at spaced apart locations. A valve 90 is provided in each discharge pipe 88 to control the release of water. The discharge pipes 88 are configured so as to be able to overlie an inlet opening of the tanks 46 and 48. This is shown most clearly for example
30 in Figures 4 and 5.

Proximity sensors 92 are provided on opposite sides of each of the discharge pipes 88. The sensors 92 provide a signal to the on-board controller 68 as well as to a control room to indicate the approach of the cleaning apparatus 14 and/or signals indicative
35 that a tank 46 is properly aligned with a discharge pipe 88 to facilitate refilling of that tank. At that time a signal can be provided to the valve 90 to allow water to flow into the corresponding tank 46/48.

The ATCS 10 may be further configured so that the cleaning apparatus 14 reduces in its speed of travel as it approaches a refilling station (i.e. discharge pipe 88). The reduction in speed may lead to a complete stop. A tank 46/48 is then located beneath a discharge pipe 88. The speed of travel of the cleaning apparatus 14 can progressively increase once filling of the tanks has been completed to its normal operating or cleaning speed.

Depending on the configuration of the cleaning apparatus 14 each of the tanks 46 and 48 may be separately and sequentially located beneath a discharge pipe 88 for refilling; or only one of these tanks need be located beneath a discharge pipe 88 and internal plumbing of the cleaning apparatus 14 operated to transfer fluid from one tank to both tanks.

When the ATCS 10 is installed it is able to operate autonomously to clean the wall 18 or other surfaces of the tunnel 16 while the tunnel 16 is fully open to traffic without the need for an on-board human operator, on-site human supervision or the erection of temporary safety barriers. Therefore embodiments of the ATCS 10 enable the cleaning of a tunnel 16 without impacting on traffic flow and without the need for human operators to be within the working tunnel.

The ATCS 10 can travel in opposite directions. Therefore once the ATCS 10 has cleaned the wall 18 travelling in one direction, it can then clean the wall at a later time travelling in the opposite direction. In order to clean both sides of a tunnel 16 it may be preferable to install two ATCS's 10, one for each side of the tunnel 16.

Figures 6 – 9 illustrate a second embodiment of the ATCS denoted as 10'. The features of the ATCS 10' that are structurally or functionally the same as those of the system 10 are denoted with the same reference numbers.

The ATCS 10' is almost identical to the ATCS 10. The substantive difference lies in that the ATCS 10' travels along a narrow path on the road 22 rather than along the top of the barrier 20. As a result of this difference the structure of the gap straddling system 76 is slightly different in the ATCS 10'. Here the gap straddling system 76 is provided with straddling frames 78 that lie in a horizontal plane slightly above the level of the road 22. The frames 78 support their respective wheels 80 so that they can rotate about vertical axes. The wheels 80 are located so that they contact or lie in

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close proximity to the barrier 20. The gap straddling system 76 operates in this embodiment to prevent the cleaning apparatus 14 from skewing into a gap 26. This is achieved by virtue of wheels 80 on the mechanism 76 being spaced so a leading one of the wheels 80 is on the opposite side of the gap 26 to the closest drive wheel 70 and
5 in contact with or close proximity to the barrier 20 before the closest drive wheel reaches the gap 26.

Figures 10 – 13 depict a third embodiment of the ATCS denoted as 10". Features of the system 10" which are the same in structure or function as those of the system 10
10 are denoted with the same reference numbers. The substantive difference between the ATCS 10 and ATCS 10" is that in the ATCS 10" the cleaning apparatus 10 is supported by the guidance system 12 and in particular the track 18. Thus the substantive weight of the cleaning apparatus 14 is carried by the rail 18. Motive power is provided to the cleaning apparatus by drive wheels 70 which run along the track 18.
15 The drive wheels 70 in this embodiment are of a similar structure to rail vehicle wheels having a tread 95 and radially extending flange 96. Thus the flange 96 provides guidance while the tread 95 provides the traction to enable the cleaning apparatus 14 to traverse a length of the tunnel 16.

20 A further difference with the ATCS 10" is the omission of the gap traversing system 76 and the inclusion of idler wheels 98 which are coupled to the frame 38. The idler wheels 98 are configured to run along or closely adjacent to a lower end of the wall 18 to maintain the cleaning apparatus 14 in a substantially vertical disposition and prevent the creation of a moment on the drive wheels 70 about the track 18.

25

Now that embodiments of the system 10 have been described in detail it will be apparent to those skilled in the relevant art that numerous modifications and variations may be made to provide alternate embodiments.

30 For example in the described embodiments the ATCS is provided with an on-board power pack 44. However in an alternate configuration power may be provided externally via electric cables or wires suspended along the tunnel 16 and an associated contact system such as a pantograph similar to that used on electric trains and trams. In this way electric power can be provided to the devices and systems of
35 the ATCS such as the drive wheels, rotating brush 40, pumps 62 and 52, sensors and the controller 68.

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In a further embodiment and in particular a slight modification of the embodiment shown in Figures 1 – 5 the guidance system 12 may comprise two tracks or rails. These comprise the track 28 as already described but also a second track or rail attached on top of or embedded in the barrier 20. In this embodiment the drive wheels
5 70 will be configured to engage or run in the second track or rail.

In a further variation particularly, but not exclusively, for the ATCS 10' shown in Figures 6 – 9 a second brushing member may be provided to specifically contact the upright surface of the barrier 20. Thus one rotating brush can be contact the wall 18 and
10 another contact the surface of the barrier 20.

In the claims which follow, and in the proceeding description, except where the context requires otherwise due to express language or necessary implication, the word “comprise” and variations such as “comprises” or “comprising” are used in an inclusive
15 sense, i.e. to specify the presence of the stated feature but not to preclude the presence or addition of further features in various embodiments of the system as disclosed herein.

CLAIMS:

1. An autonomous surface cleaning system comprising:
a guidance system; and
5 a cleaning apparatus;
wherein the guidance system is capable of guiding the cleaning apparatus along at least a portion of the tunnel and the cleaning apparatus is capable of autonomously traveling along the tunnel under guidance of the guidance system and cleaning a length of the tunnel while it travels along the tunnel.
10
2. The autonomous surface cleaning system according to claim 1 wherein the guidance system comprises at least one track extending along the tunnel.
3. The autonomous surface cleaning system according to claim 2 wherein the at
15 least one track comprises a first track supported on a wall of the tunnel and a second track on a barrier disposed along the tunnel.
4. The autonomous surface cleaning system according to claim 3 wherein the second track comprises: (a) an upper horizontal surface or edge of the barrier or (b) a
20 rail that is supported on or in the barrier.
5. The autonomous surface cleaning system according to any one of claims 1-4 comprising a gap straddling system coupled to the cleaning apparatus to enable the cleaning apparatus to a gap along the length of the tunnel.
25
6. The autonomous surface cleaning system according to claim 5 wherein gap straddling system comprises two straddling mechanism, one on each side of the cleaning apparatus.
- 30 7. The autonomous surface cleaning system according to claim 6 wherein each straddling mechanism comprises a straddle frame and two spaced apart contact members supported on the straddle frame.
8. The autonomous surface cleaning system according to claim 7 wherein the
35 contact members comprise guide wheels and wherein the guide wheels on each straddle frame are spaced by a distance sufficient to so that each guide wheel can be in contact with a surface on opposite sides of the gap.

9. The autonomous surface cleaning system according to any one of claims 1-8 comprising powered traction system coupled to the cleaning apparatus and capable of propelling the cleaning apparatus along the tunnel.
- 5 10. The autonomous surface cleaning system according to claim 9 wherein the powered traction system comprises at least one driven wheel.
11. The autonomous surface cleaning system according to claim 9 wherein at least
10 one driven wheel is arranged to engage a road in the tunnel.
12. The autonomous surface cleaning system according to any one of claims 1-11 comprising at least one brushing member capable of physically brushing a surface of the tunnel being cleaned when the cleaning apparatus travels along the tunnel.
- 15 13. The autonomous surface cleaning system according to claim 12 wherein the at least one brushing member is powered to move relative to a support frame of the cleaning apparatus.
- 20 14. The autonomous surface cleaning system according to claim 13 wherein the at least one brushing member is powered to rotate as it contacts the surface being cleaned.
- 25 15. The autonomous surface cleaning system according to any one of claims 1-14 comprising a cleaning fluid delivery system arranged to deliver cleaning fluid onto the surface being cleaned.
- 30 16. The autonomous surface cleaning system according to claim 15 wherein the cleaning fluid delivery system comprises at least one fluid spray manifold arranged to spray cleaning fluid onto the length of the tunnel as the cleaning apparatus travels along the length of the tunnel.
- 35 17. The autonomous surface cleaning system according to claim 15 wherein the cleaning fluid delivery system comprises first and second spray manifolds arranged on opposite sides of the brushing member wherein the spray manifolds are operable to spray cleaning fluid onto the length of the tunnel either: (a) in advance of the brushing member; (b) trailing the brushing member; or (c) both in advance of and trailing the

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cleaning apparatus.

18. The autonomous surface cleaning system according to any one of claims 15-17 wherein the cleaning fluid delivery system is arranged to deliver more than one
5 different type of cleaning fluid onto the surface being cleaned.

19. The autonomous surface cleaning system according to any one of claims 15-18 wherein the cleaning fluid delivery system comprises at least one tank for holding a volume of a first cleaning fluid.

10

20. The autonomous surface cleaning system according to claim 19 wherein the cleaning fluid delivery system comprises at least one tank for holding a volume of a second cleaning fluid.

- 15 21. The autonomous surface cleaning system according to claim 19 wherein, cleaning fluid delivery system is arranged to deliver the second fluid on the surface being cleaned wall either (a) separately to the first cleaning fluid; or (b) as a mixture with the first cleaning fluid.

- 20 22. The autonomous surface cleaning system according to claim 20 or 21 comprising a cleaning fluid supply extending along the length of the tunnel and arranged to fill at least the tank or tanks for holding the first cleaning fluid at one or more spaced apart refill locations along the track.

- 25 23. The autonomous surface cleaning system according to claim 22 wherein the autonomous tunnel cleaning system is arranged such that travel speed of the cleaning apparatus: progressively reduces from a cleaning speed as the cleaning apparatus approaches a refill location to zero when it reaches the refill location; and, after refilling of the tank or tanks for holding the first cleaning fluid, progressive increase from zero
30 toward the cleaning speed.

24. The autonomous surface cleaning system according to any one of claims 1-23 comprising an on-board power pack capable of providing operational power to the cleaning apparatus.

35

25. The autonomous surface cleaning system according to any one of claims 1-24 comprising an on-board controller capable of controlling operation of the cleaning

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apparatus in response to signals received from on-board sensors and/or signals sent from a remote location. .

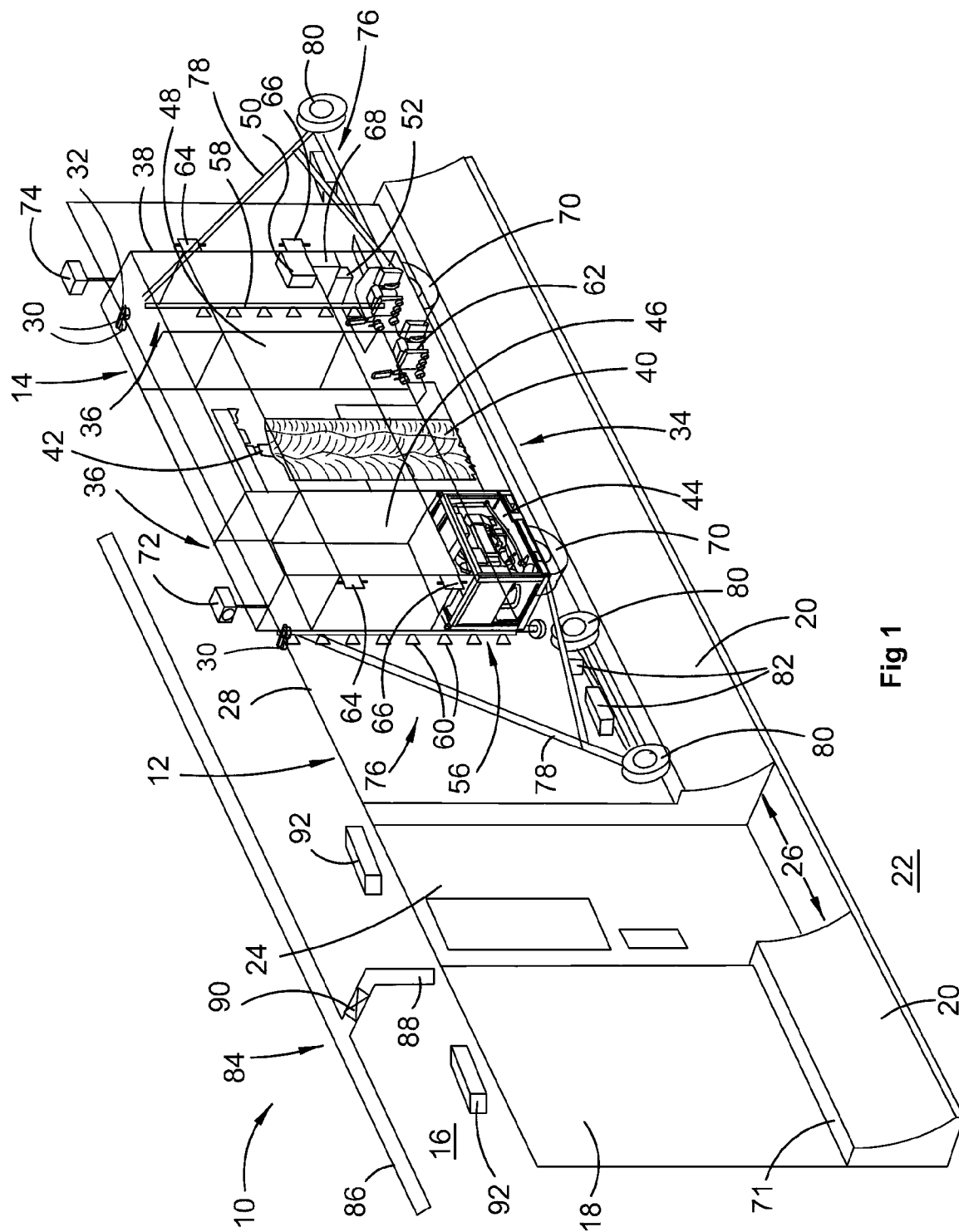


Fig 1

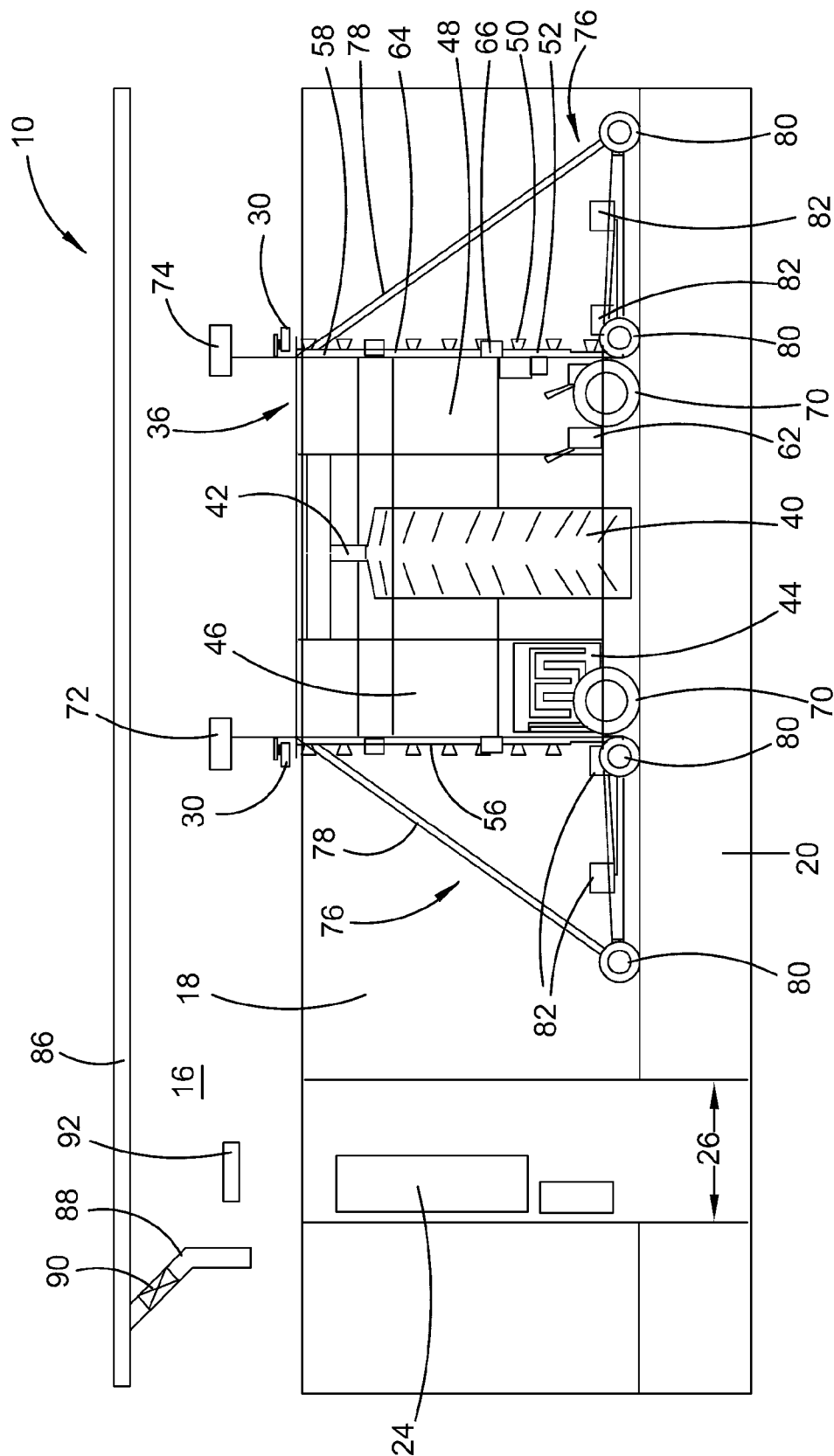


Fig 2

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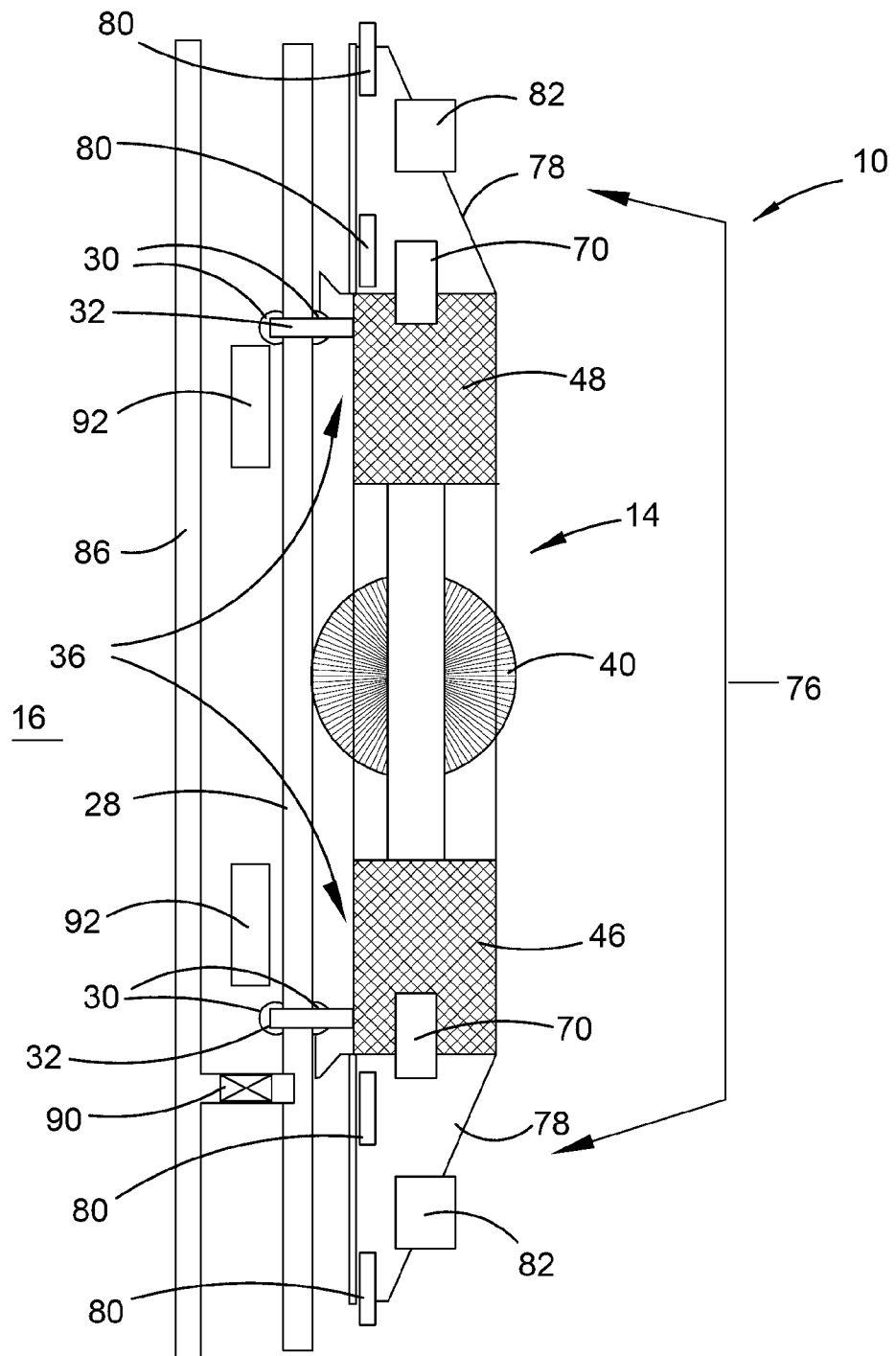


Fig 3

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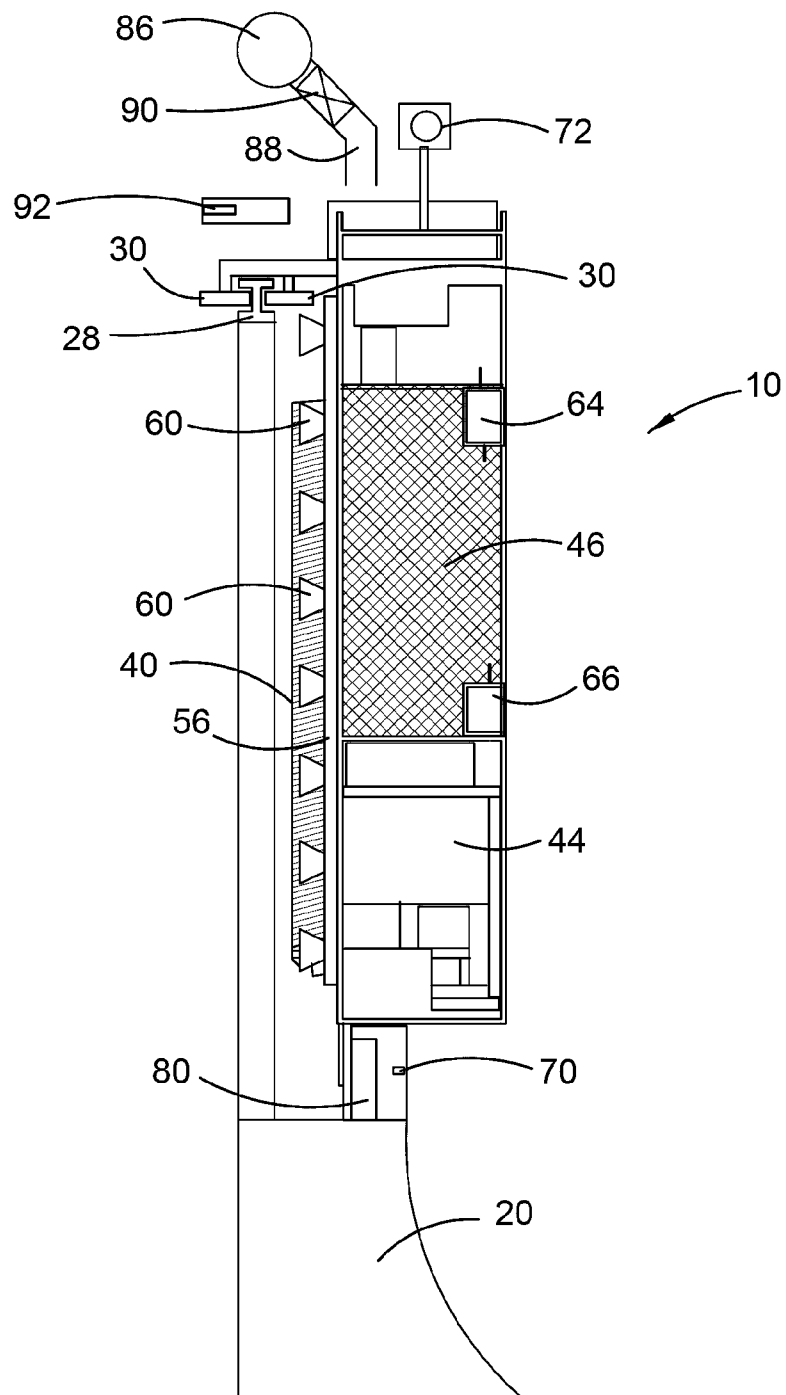


Fig 4

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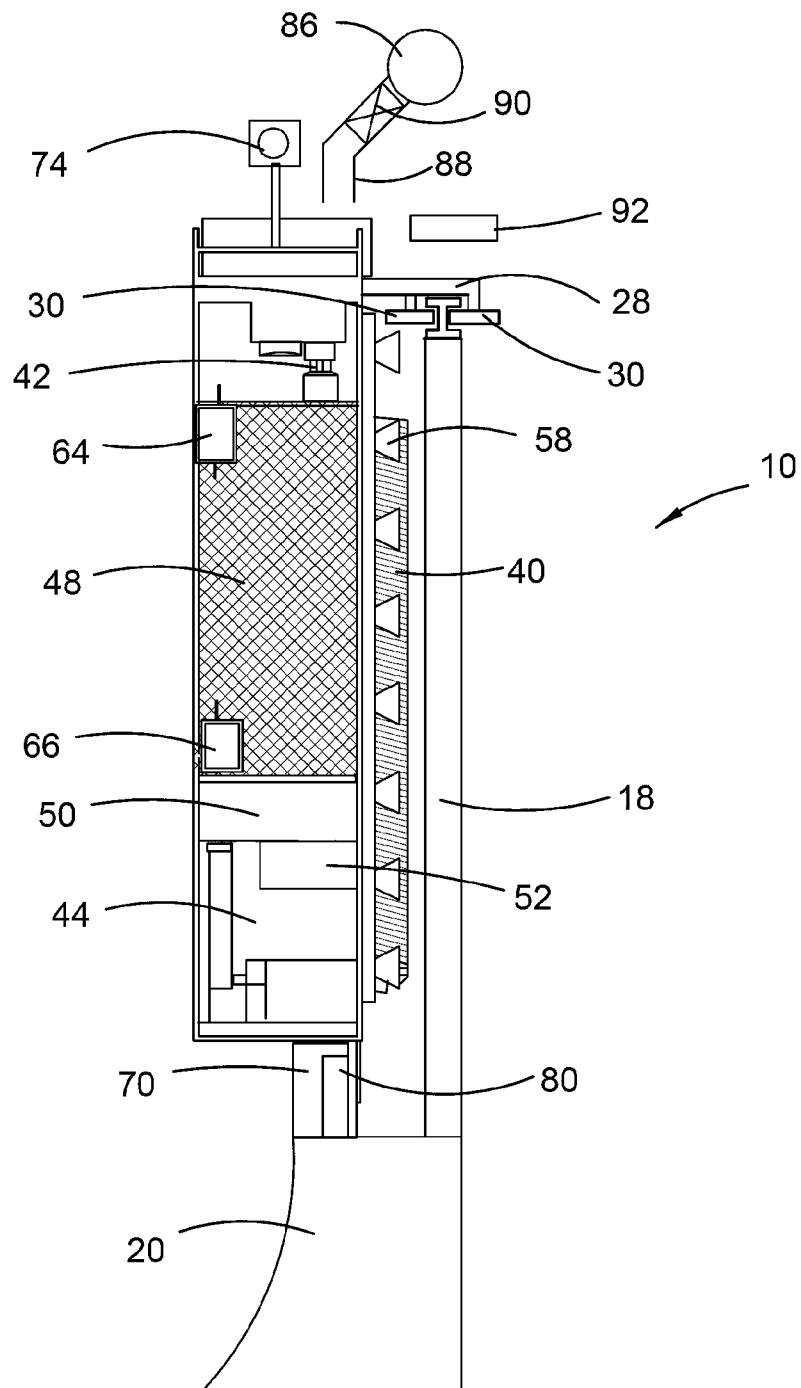


Fig 5

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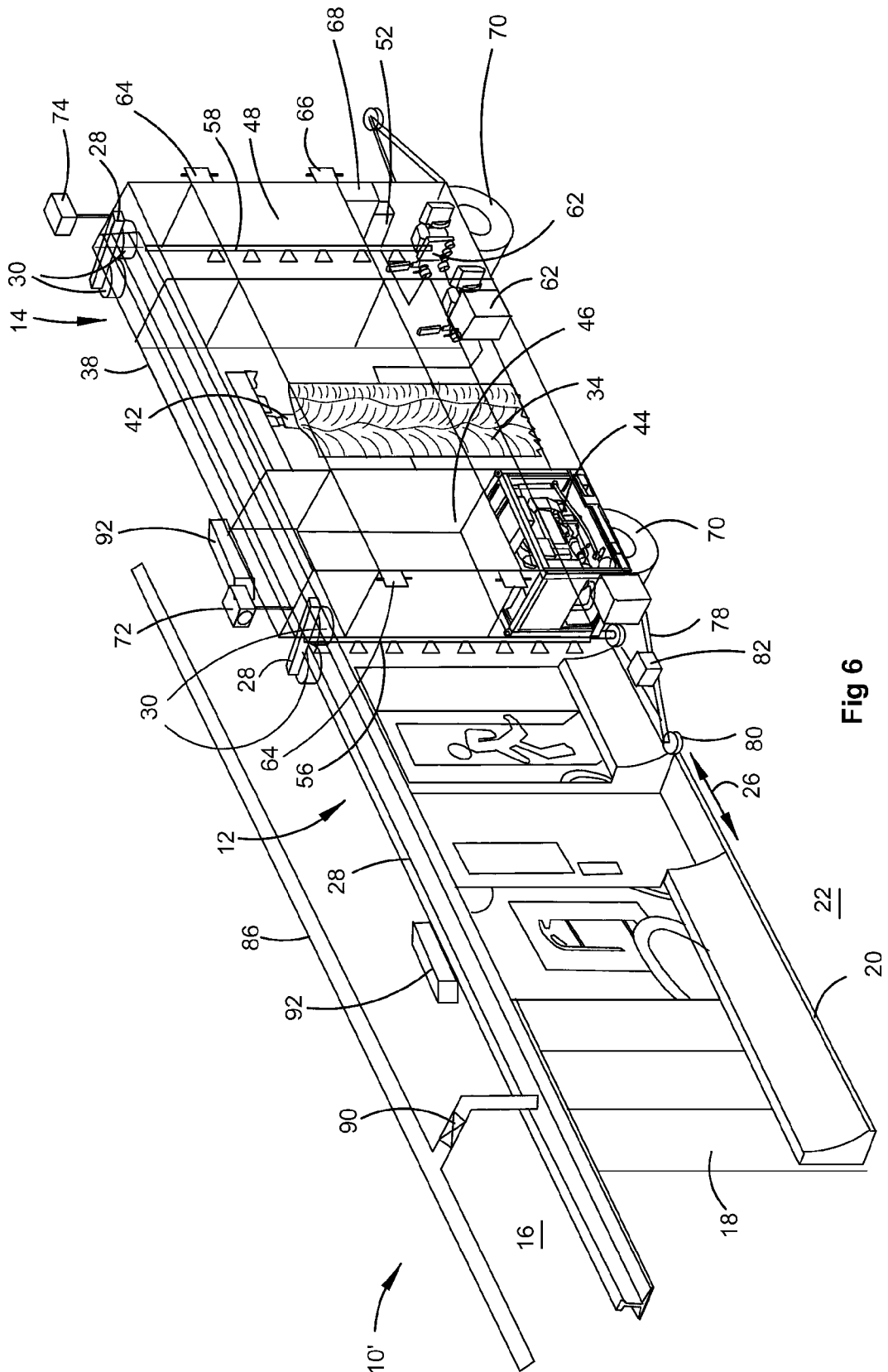
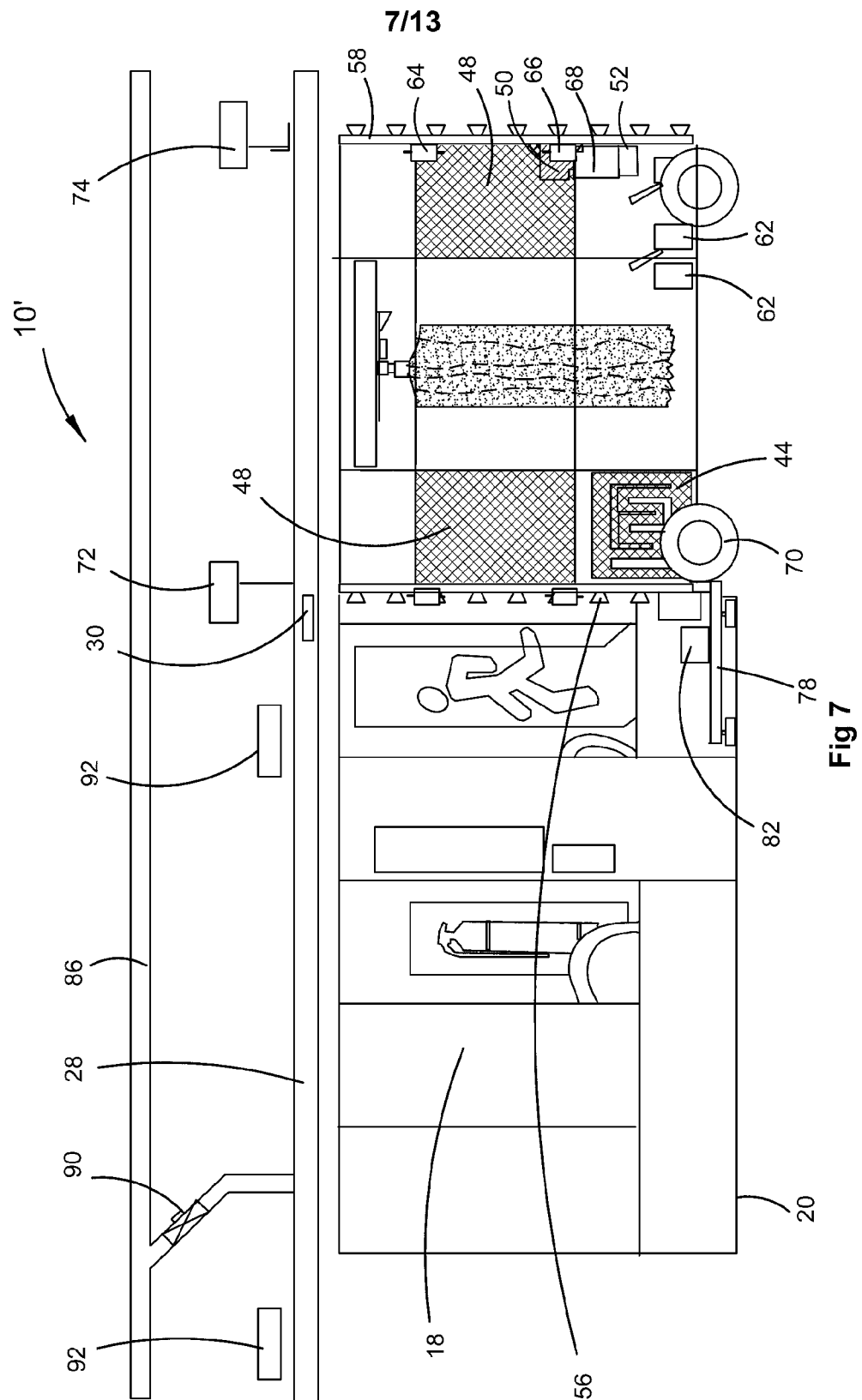


Fig 6



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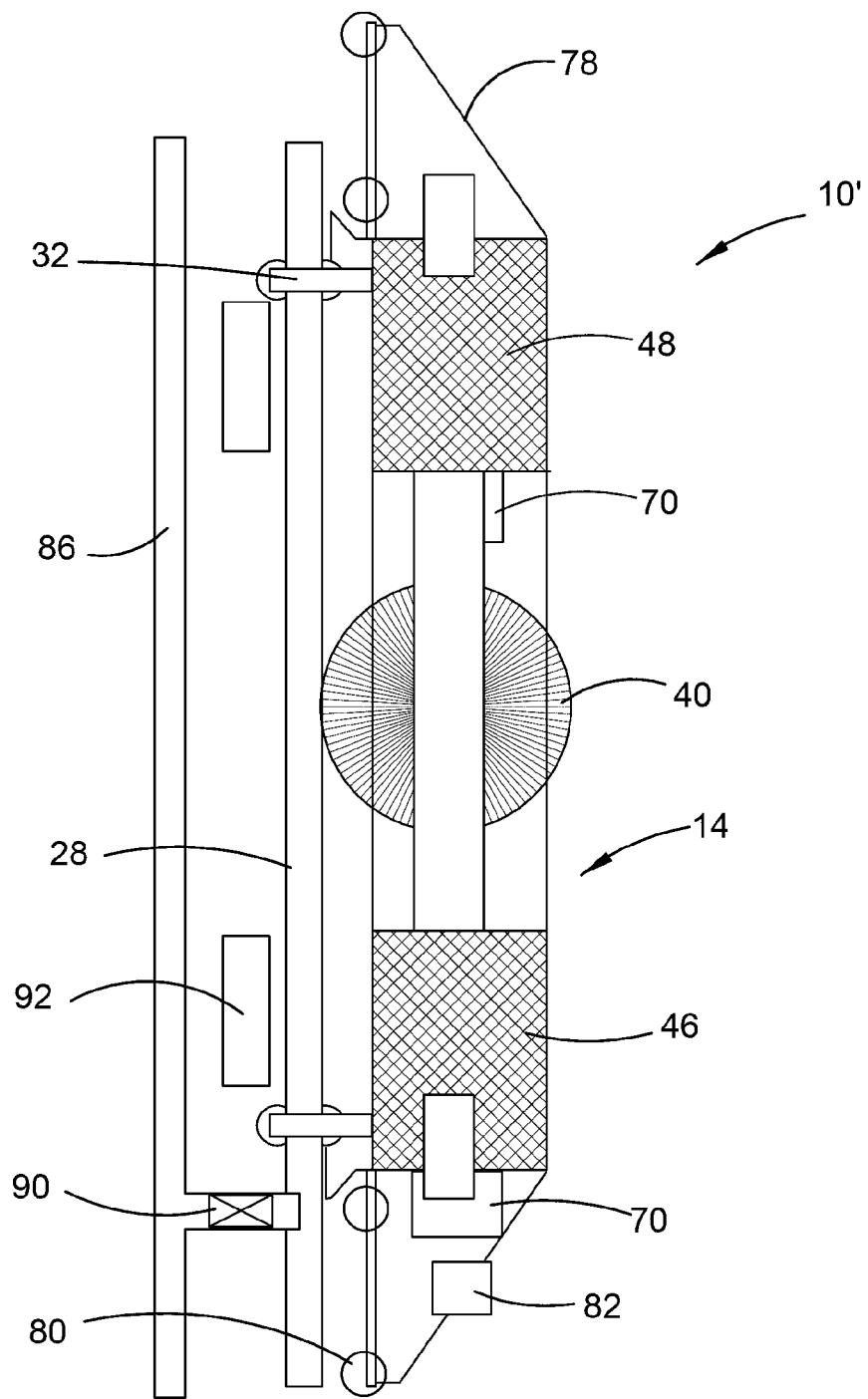


Fig 8

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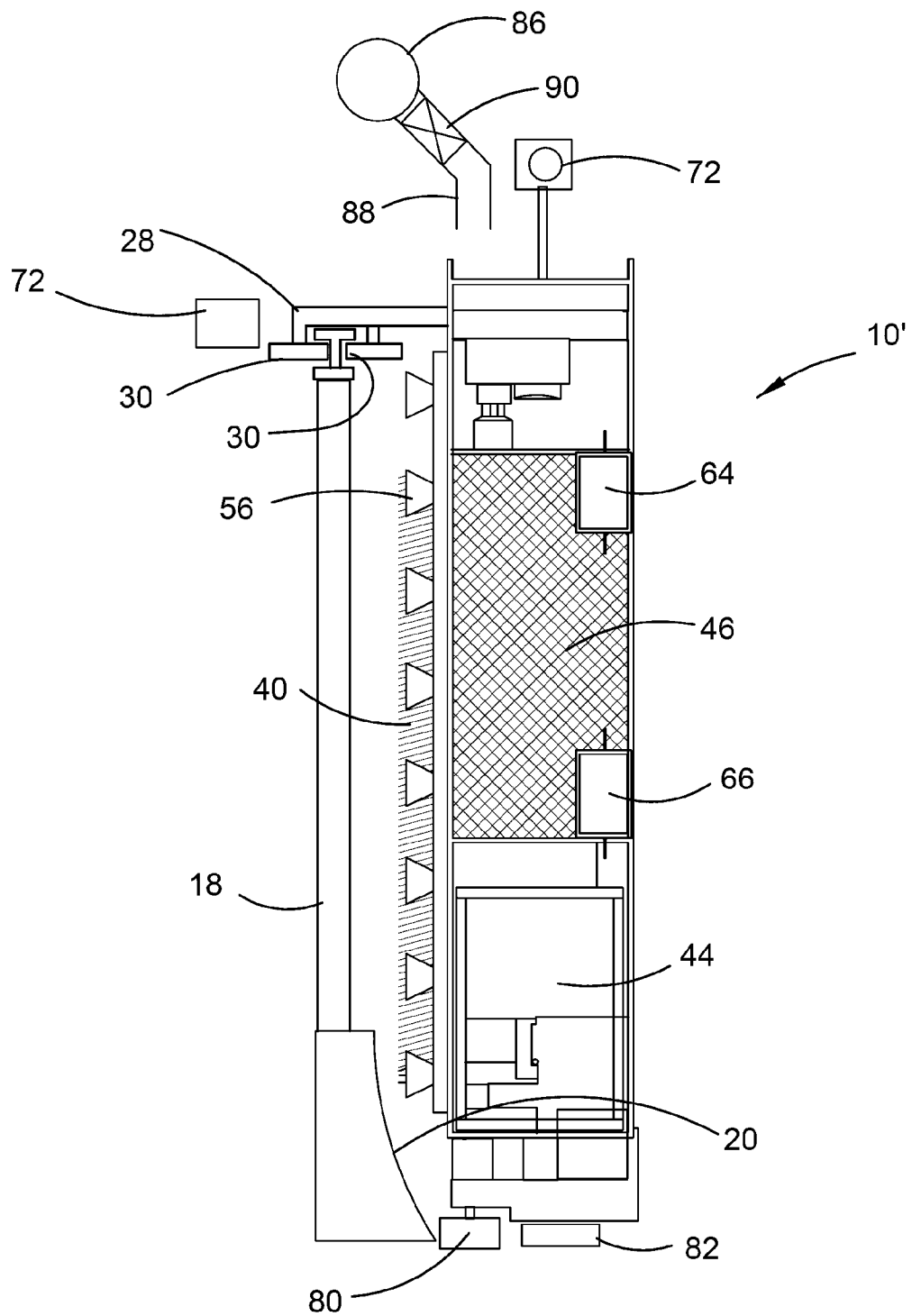


Fig 9

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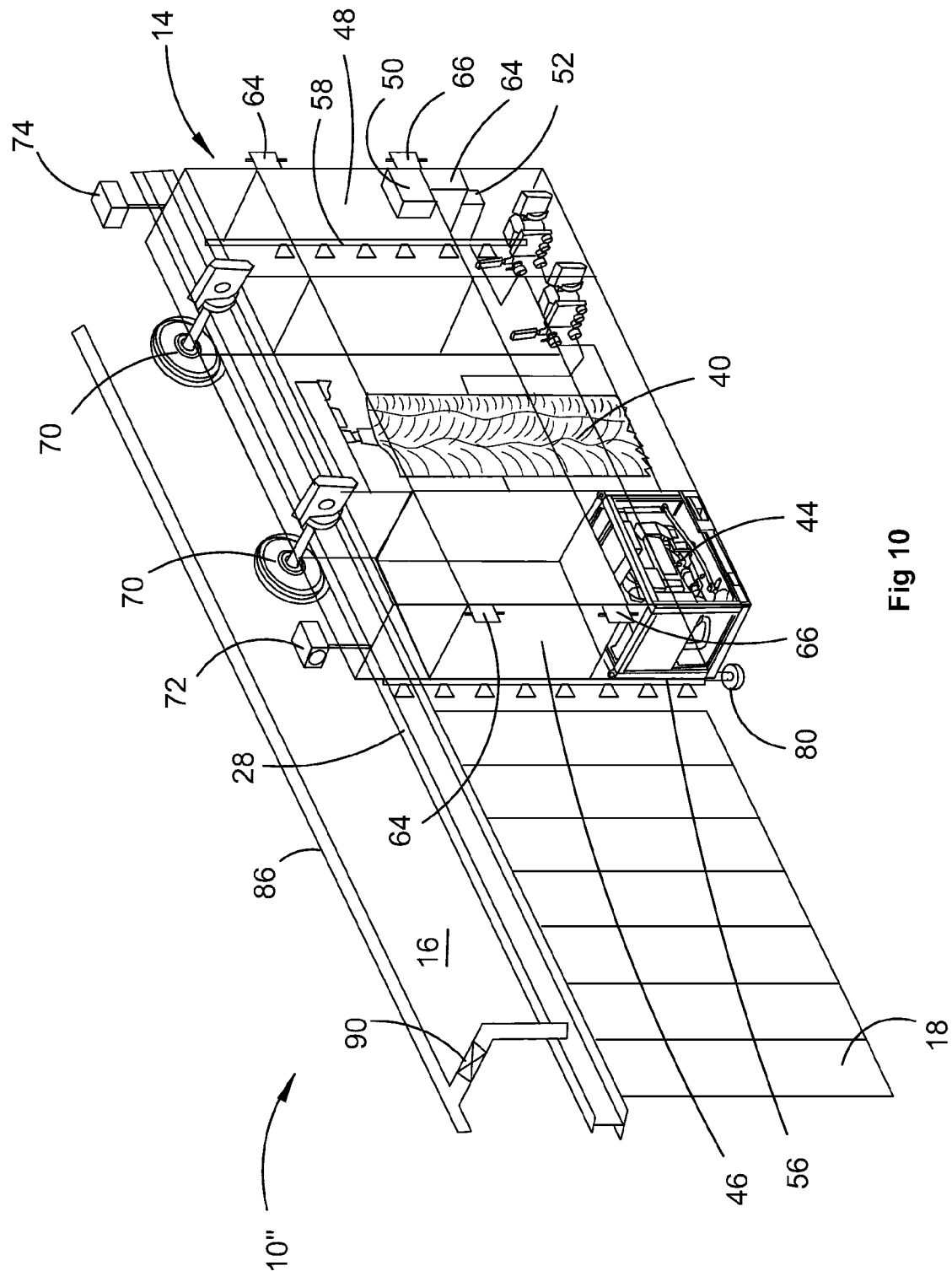


Fig 10

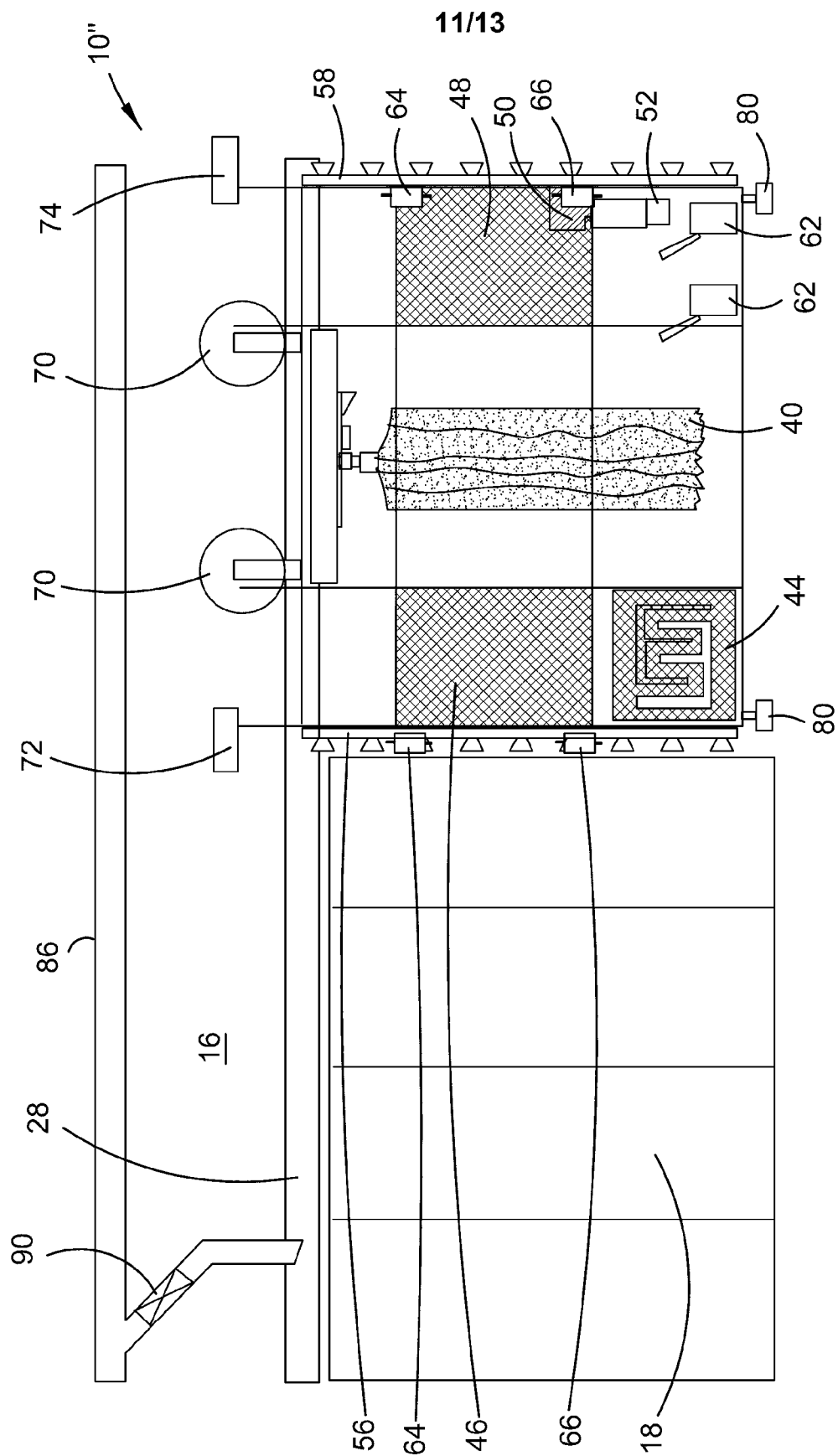


Fig 11

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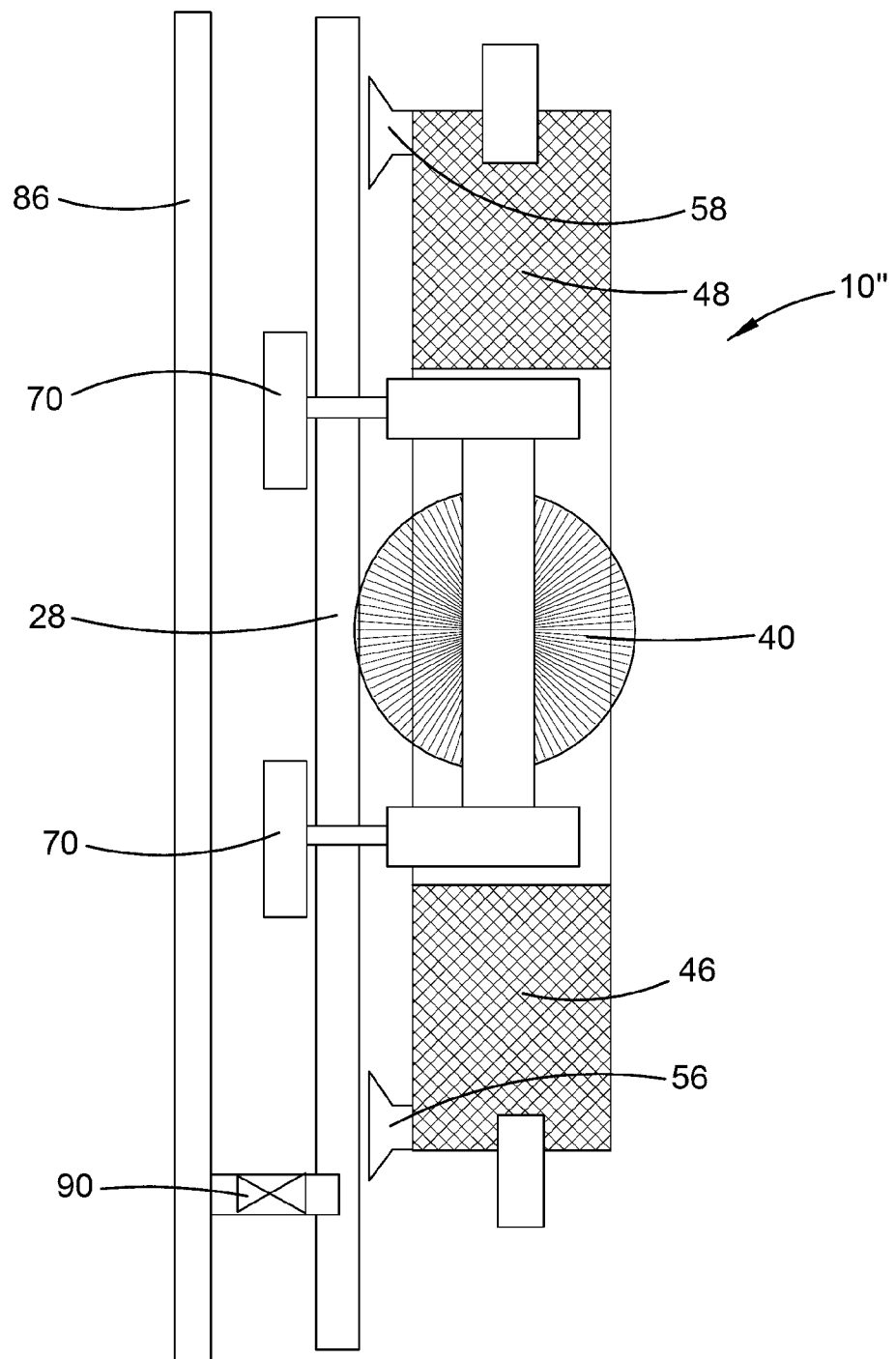


Fig 12

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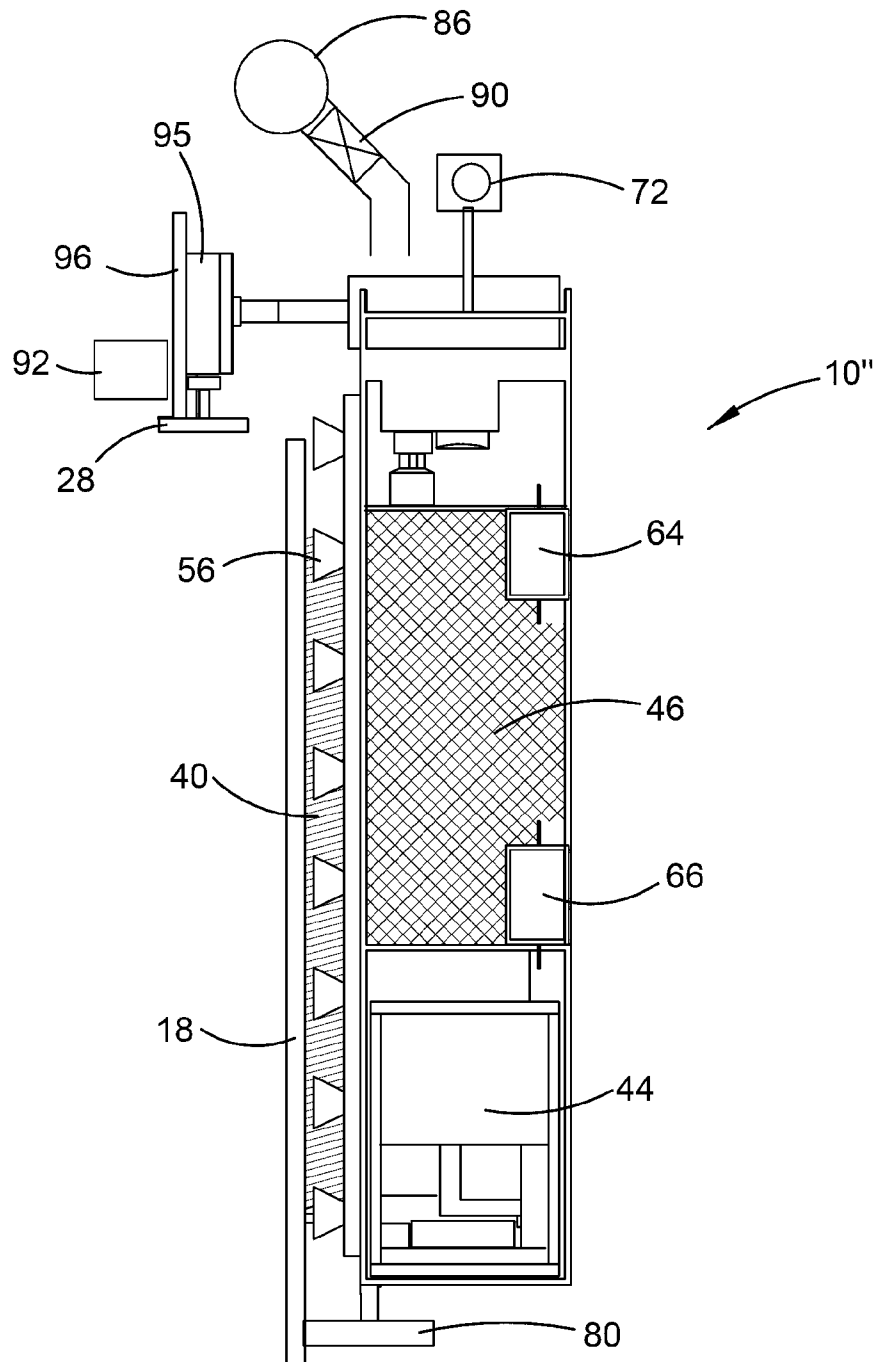


Fig 13

INTERNATIONAL SEARCH REPORT

 International application No.
PCT/AU2015/000086

A. CLASSIFICATION OF SUBJECT MATTER

E01H 1/00 (2006.01) E21F 17/00 (2006.01) B60P 3/30 (2006.01) B08B 7/04 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC and WPI/IPC/CPC B08B OR E01H1 OR E21F17/00 AND Keywords ((TUNNEL+ OR SUBWAY OR UNDERPASS) 6D (CLEAN+ OR SCRUB+ OR SANIT+ OR SCOUR+ OR STERIL+ OR WASH+ OR MAINTENANCE)) and Keywords (auto+, road) & like terms. Cluster - \$PATEN-English full text databases EPODOC, WPIAP, TXPEA, TXPEB, TXPEC, TXPEE, TXPEF, TXPEH, TXPEI, TXPEP, TXTPEPEA, TXPES, TXPUSE0A, TXPUSE1A, TXPUSEA, TXPUSEB, TXPW0EA and Keywords (auto, road) & like terms.

EPODOC and WPI/IPC/CPC B08B OR E01H1/00 OR E01H1/005 OR E21F17/00 OR G05B19 OR B60P3/30 AND Keywords ((ROAD OR CAR OR VEHICLE OR AUTOMOBILE OR FREE WAY OR HIGH WAY OR METRO OR TRAFFIC OR MOTOR CAR OR TRANSPORT+ OR TRANSIT+) 6D (TUNNEL OR SUB WAY OR UNDER PASS)) and Keywords (unmanned, rail+) & like terms. Transferred results to cluster: Cluster - \$PATEN- English full text databases EPODOC, WPIAP, TXPEA, TXPEB, TXPEC, TXPEE, TXPEF, TXPEH, TXPEI, TXPEP, TXTPEPEA, TXPES, TXPUSE0A, TXPUSE1A, TXPUSEA, TXPUSEB, TXPW0EA and Keywords (unmanned, rail+) & like terms. Espacenet and keywords (tunnel washing AND B08B). AusPat ("Jones, Stuart" IN INV).

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

☒ Further documents are listed in the continuation of Box C

 ☒ See patent family annex

* "A"	Special categories of cited documents: document defining the general state of the art which is not considered to be of particular relevance	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E"	earlier application or patent but published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 1 April 2015	Date of mailing of the international search report 01 April 2015
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA Email address: pct@ipaustalia.gov.au	Authorised officer John Deuis AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. 0262832146

INTERNATIONAL SEARCH REPORT		International application No.
C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		PCT/AU2015/000086
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1273711 A2 (Bettella S.r.l.) 08 January 2003 See the abstract; para. [0001], [0007]-[0034]; figures 1-5; and claims 1 to 21.	1-4, 9-17, 19, 24-25
Y	See figure 2 items (20, 18); and para. [0020]-[0025].	18, 20-23
Y	JPH 07247800 A (MITSUBISHI HEAVY IND LTD) 26 September 1995 See para. [0015]-[0016]; and figure 1.	18, 20-23

Form PCT/ISA/210 (fifth sheet) (July 2009)

INTERNATIONAL SEARCH REPORT Information on patent family members		International application No. PCT/AU2015/000086	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
EP 1273711 A2	08 January 2003	IT PD20010164 A1	07 Jan 2003
JPH 07247800 A	26 September 1995	None	
End of Annex			
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001. Form PCT/ISA/210 (Family Annex)(July 2009)			