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United States Patent [19]

Watkin

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[54] **OSCILLATING BLAST CLEANER**

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[73] Assignee: **United States Filter Corporation**, Palm Desert, Calif.

[21] Appl. No.: **730,162**

[22] Filed: **Oct. 15, 1996**

Related U.S. Application Data

[63] Continuation of Ser. No. 255,386, Jun. 8, 1994, abandoned, which is a continuation-in-part of Ser. No. 183,194, Jan. 14, 1994, abandoned.

[51] **Int. Cl.**[6] **B24C 3/06**

[52] **U.S. Cl.** **451/92**; 451/2

[58] **Field of Search** 451/2, 3, 75, 87–89, 451/92

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Primary Examiner—Timothy V. Eley

Attorney, Agent, or Firm—Wolf, Greenfield & Sacks, P.C.

[57] **ABSTRACT**

The cleaning apparatus of the invention consists of a blast machine mounted on a support structure for oscillating motion relative thereto. In one embodiment, the blast machine consists of a blast wheel for projecting abrasive onto the surface, a hopper for collecting the spent abrasive and debris, a screw conveyor for returning the spent abrasive and debris to a separator where the debris is separated from the abrasive and the abrasive is returned to the blast wheel. The support structure is supported against the surface being cleaned on sleds or wheels. On a vertical surface the cleaning apparatus is raised by a winch and on a horizontal surface the wheels can be power driven. The blast machine is arranged with its axis of rotation perpendicular to the path of travel of the apparatus and is simultaneously oscillated relative to the support structure in a direction perpendicular to the path of travel of the support structure by a fluid cylinder and cable arrangement. As a result, the blast machine is able to clean or otherwise treat a path as wide as the range of oscillation with minimum overlap of adjacent paths.

12 Claims, 8 Drawing Sheets

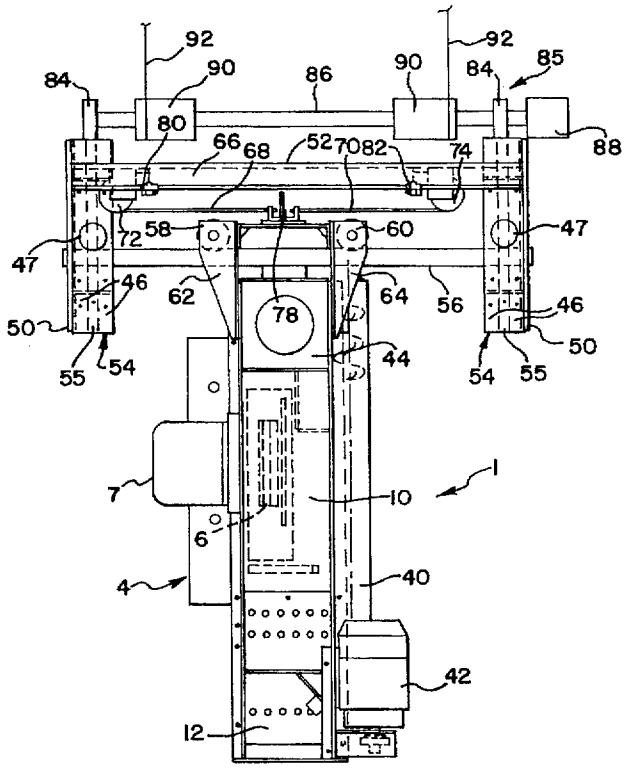
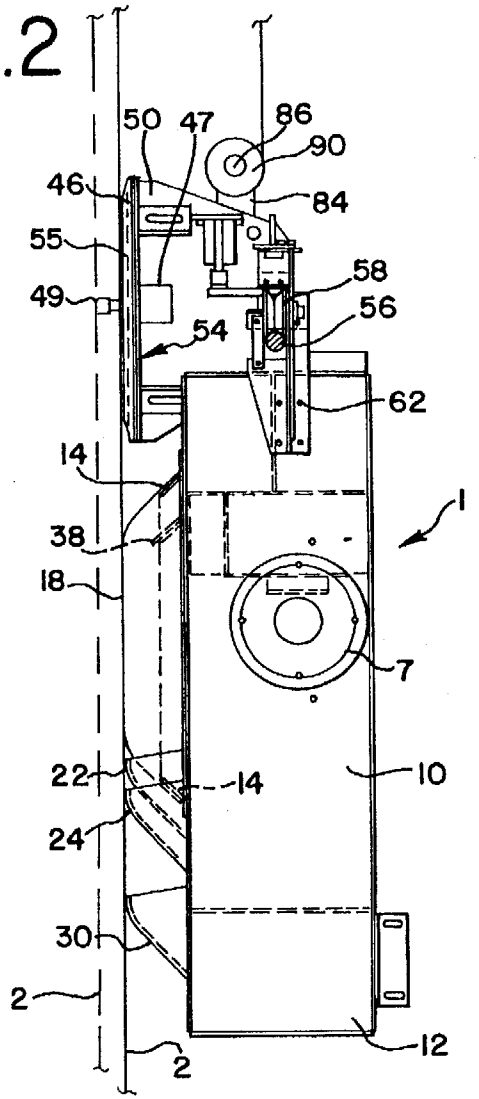


FIG.2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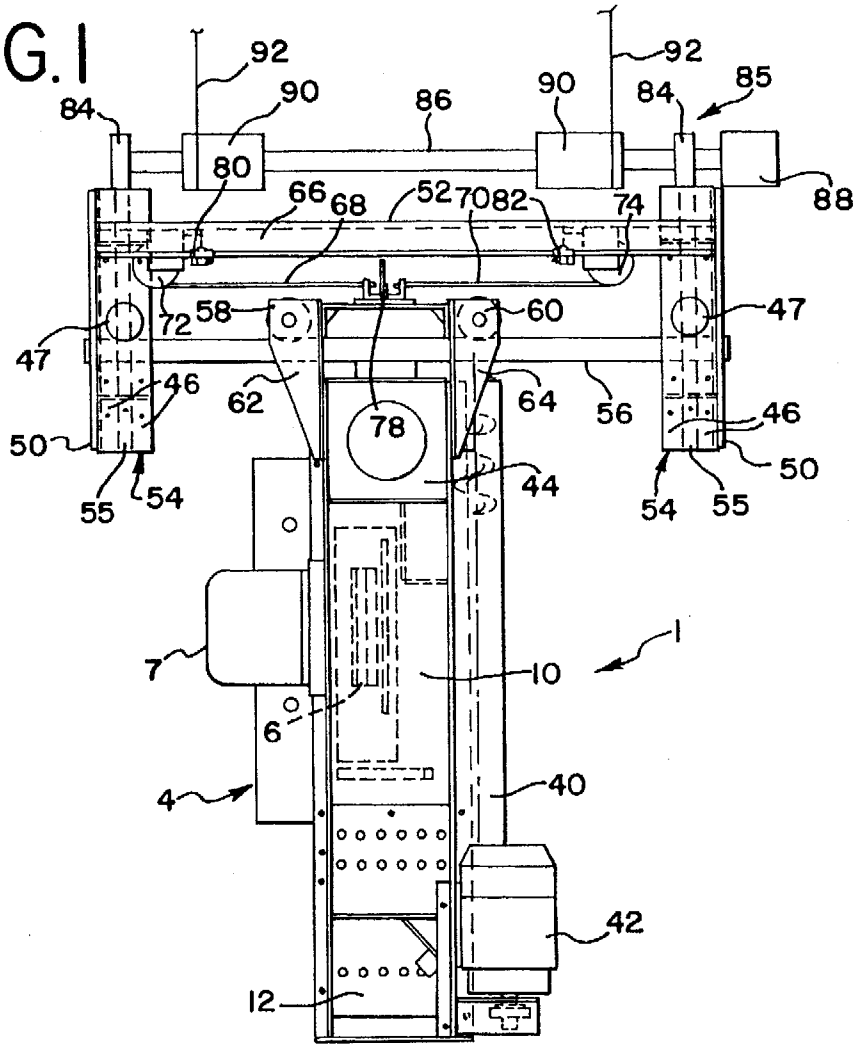
2

FIG.1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88
66
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52
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46
62
64
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55
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44
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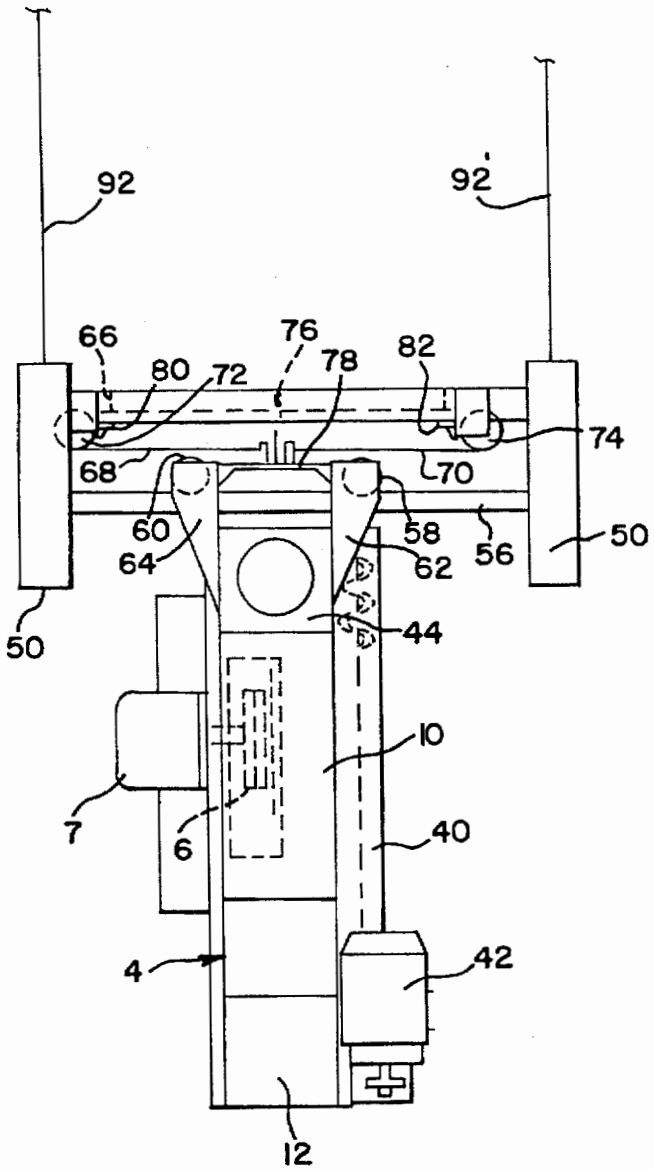
1
7
10
6
4
40
42
12

FIG.6


92
92'
66
76
78
82
80
72
74
68
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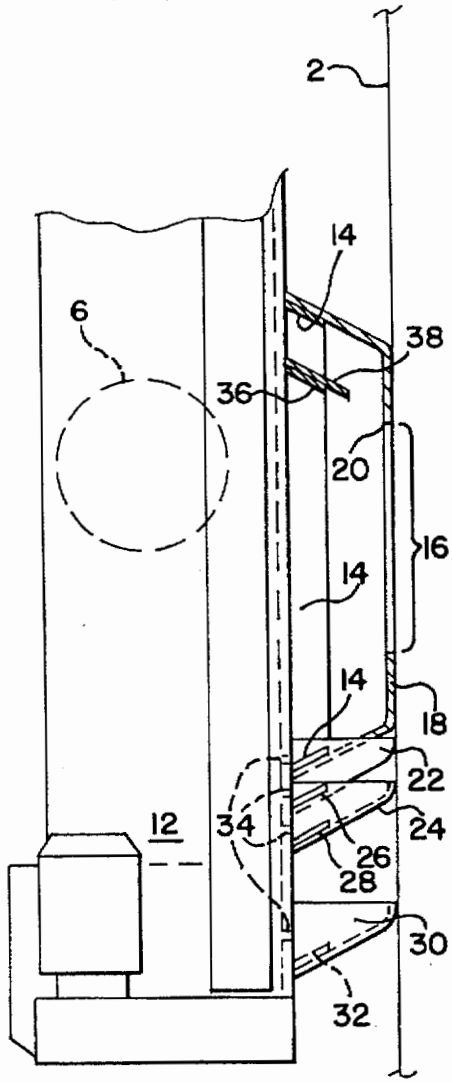
56
50
50
44
10
7
6
40
4
42
12

FIG.3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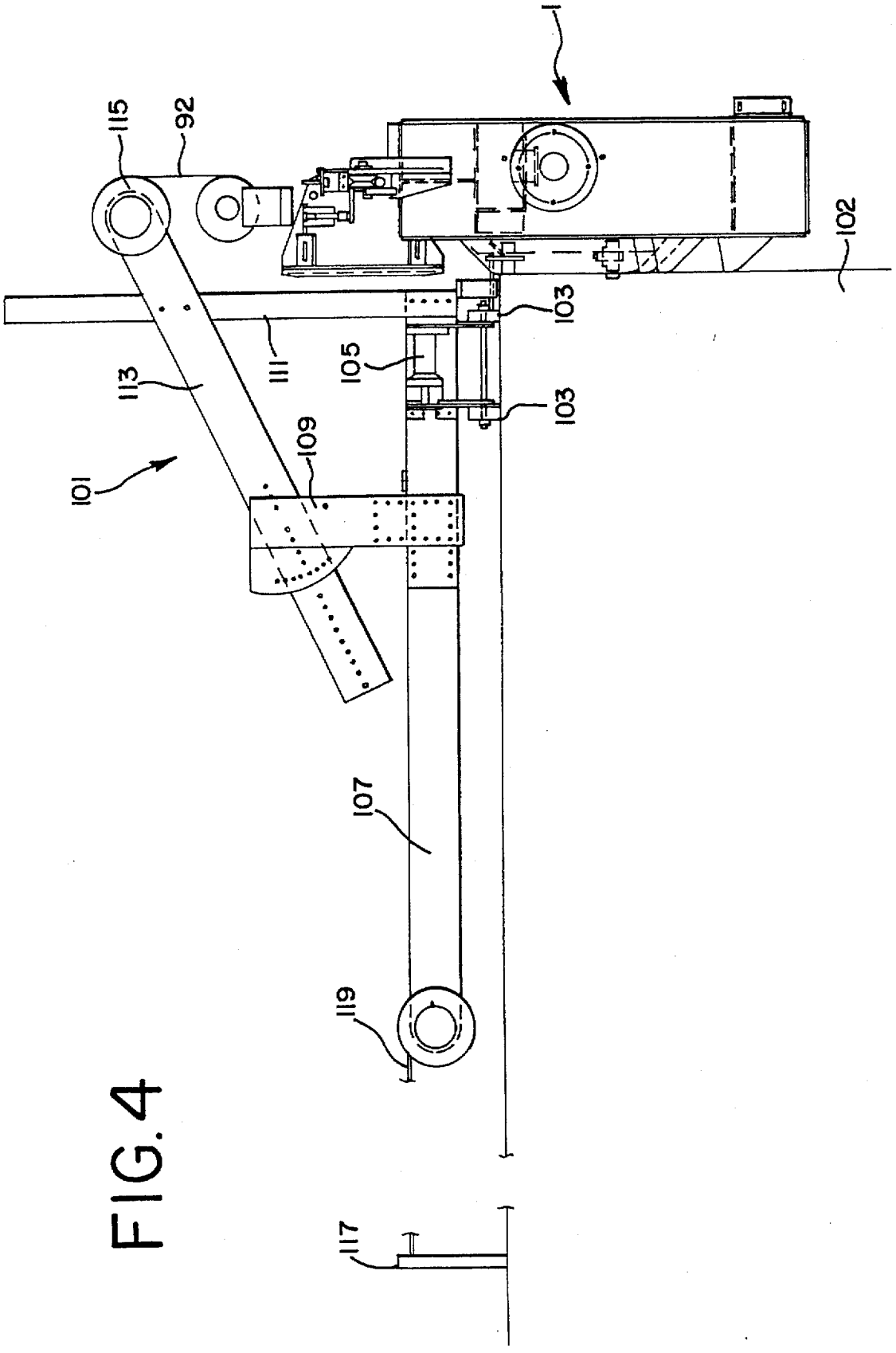


FIG. 4

FIG. 5

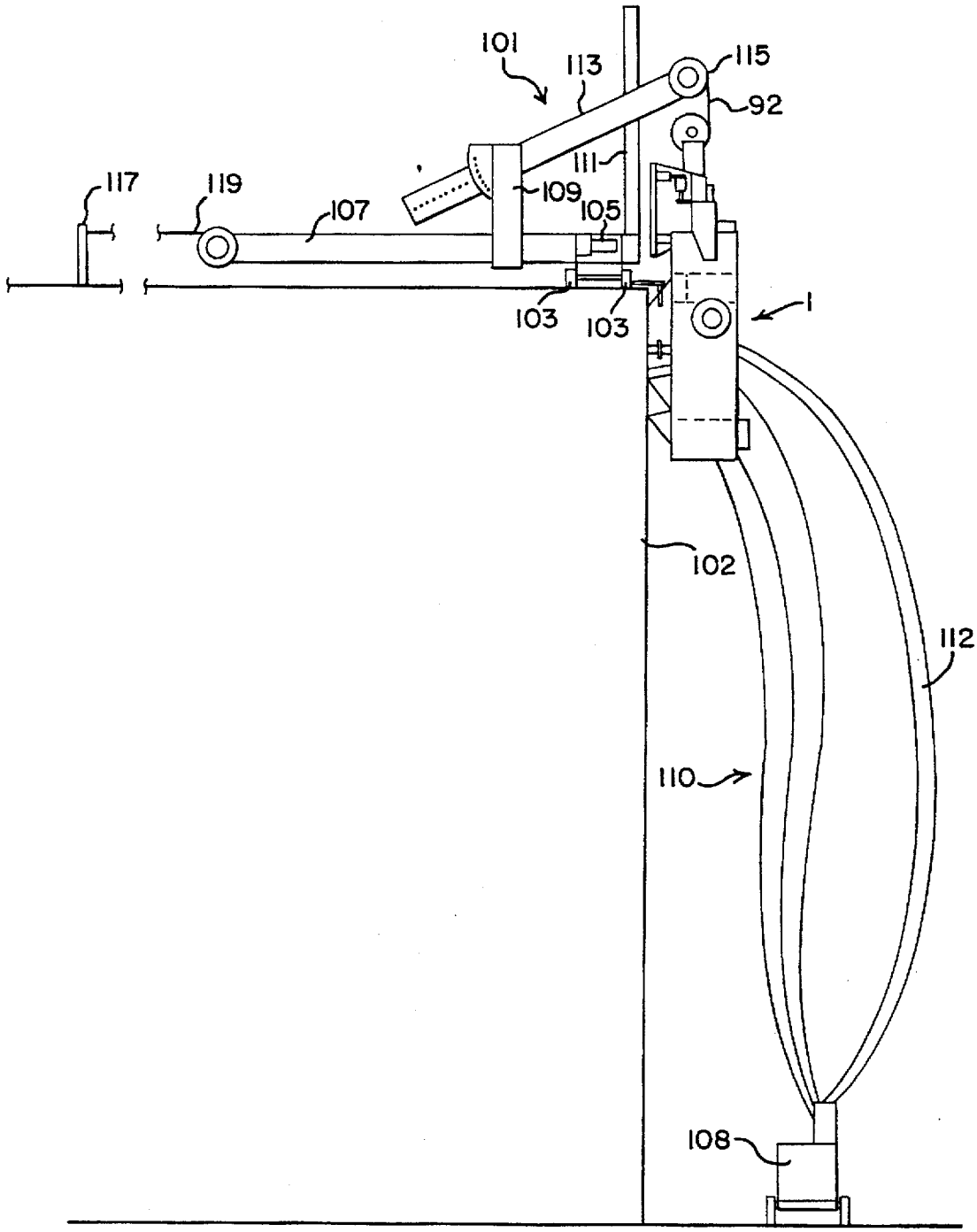


FIG. 8

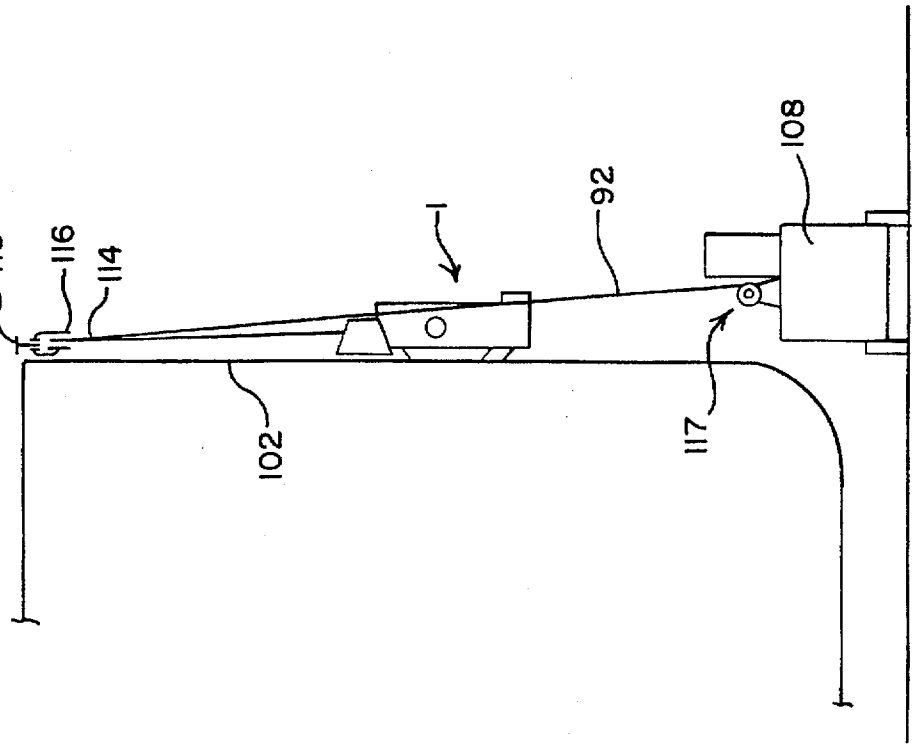
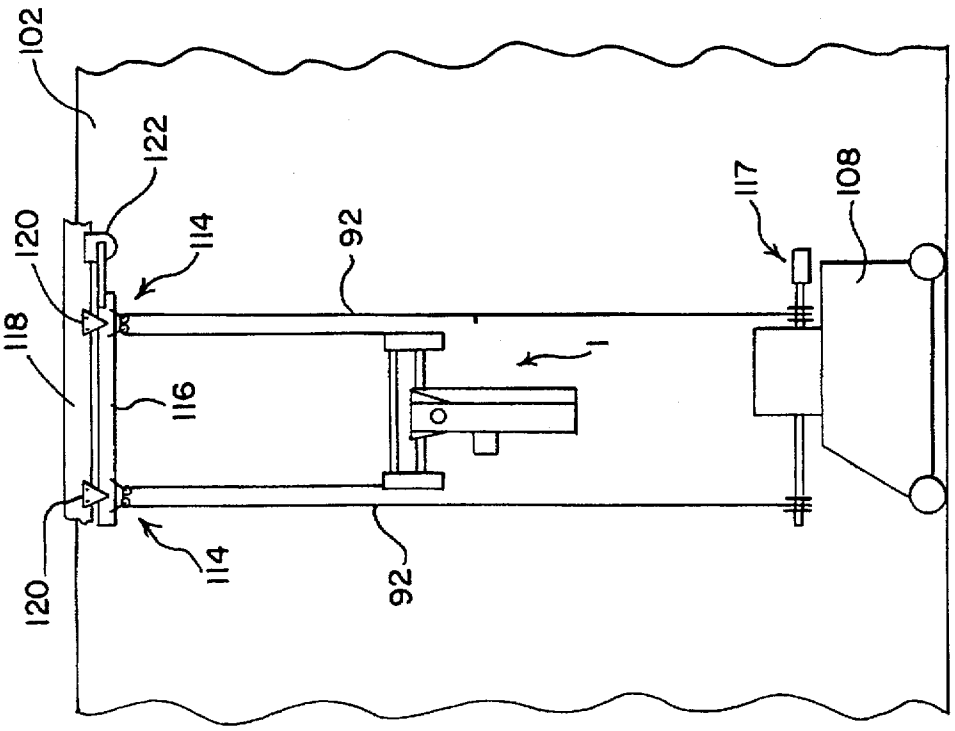

118
116
114
1
92
108
102
117

FIG. 7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122
120
114
92
117
108
118
116
1
120
114
92

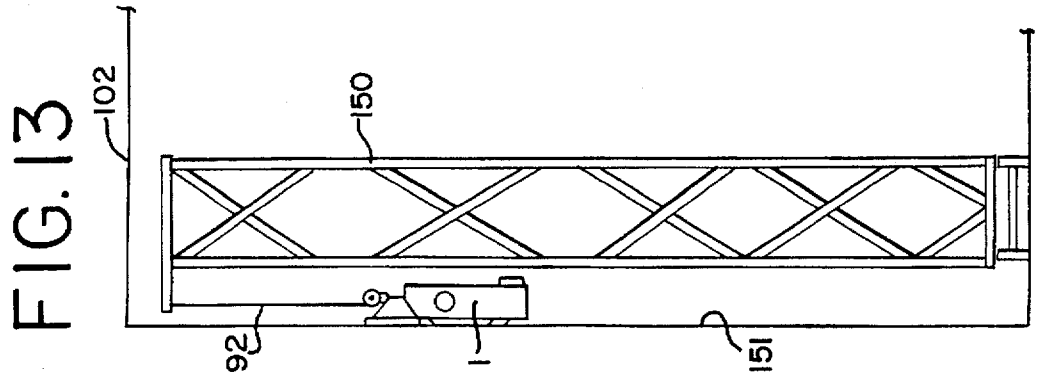


FIG. 13

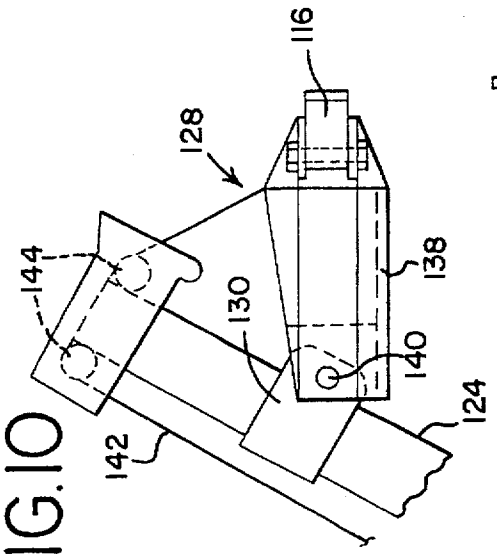


FIG. 10

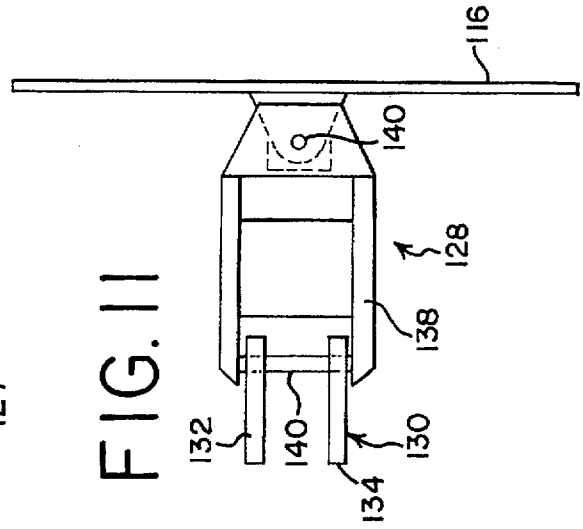


FIG. 11

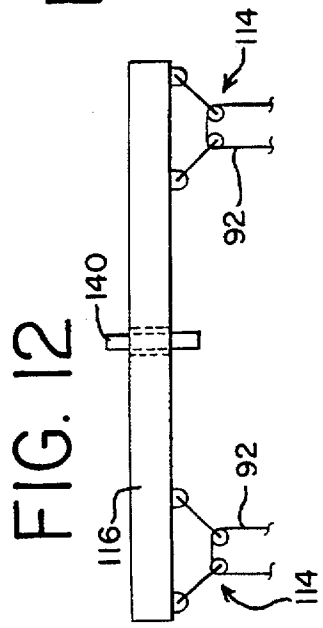


FIG. 12

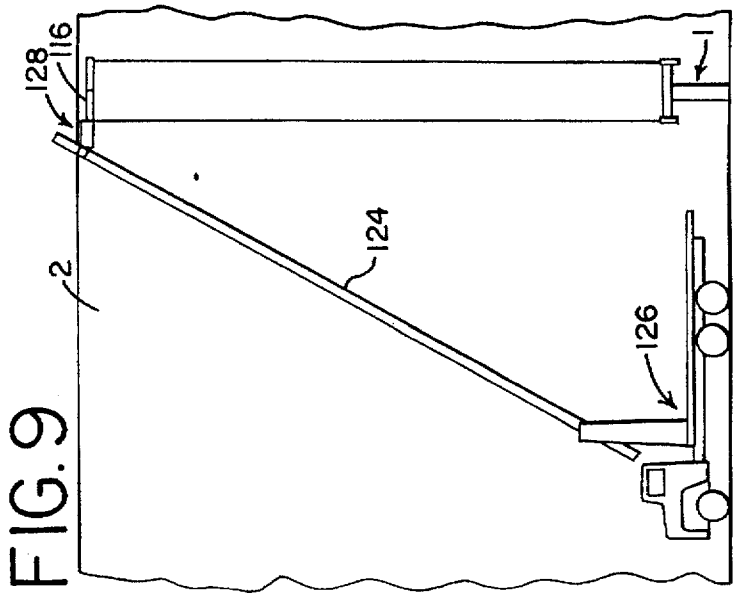
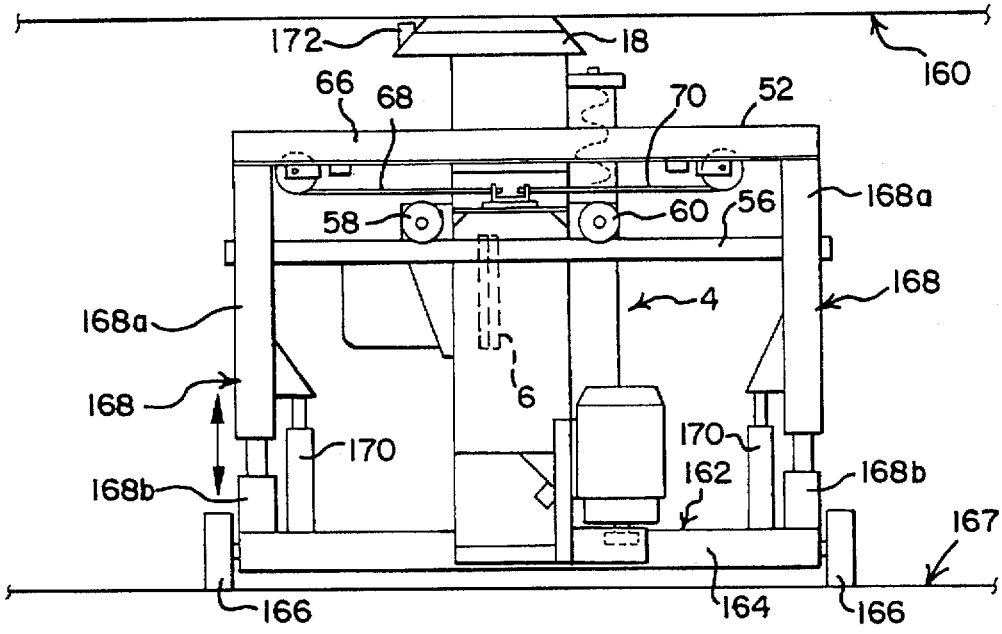


FIG. 9

FIG. 14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66
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168a
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168b
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FIG. 15

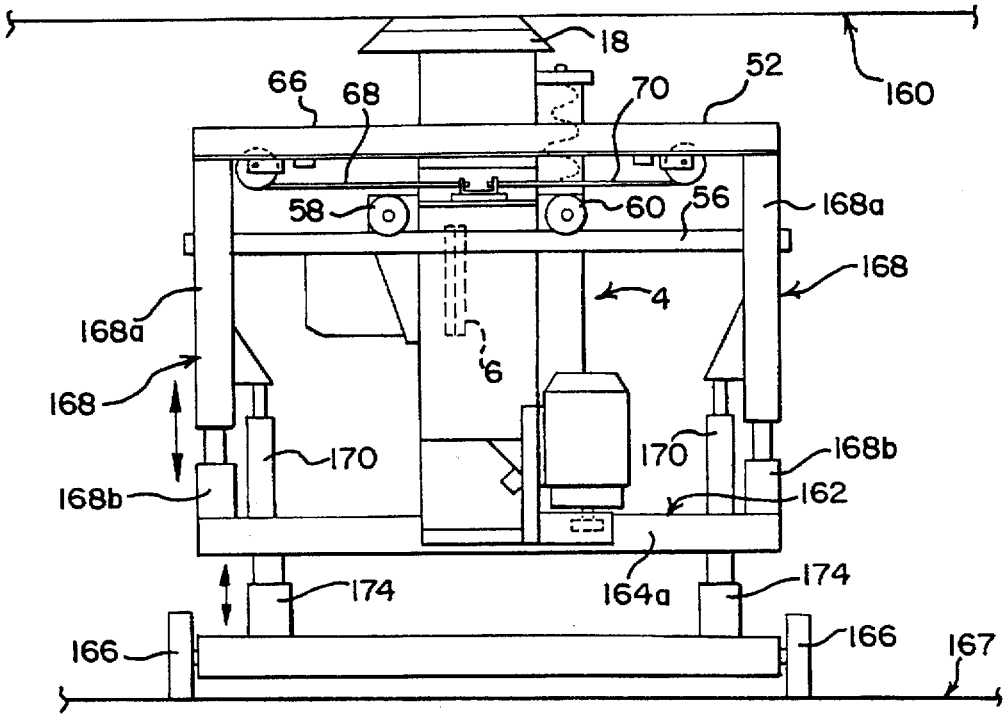
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FIG. 16

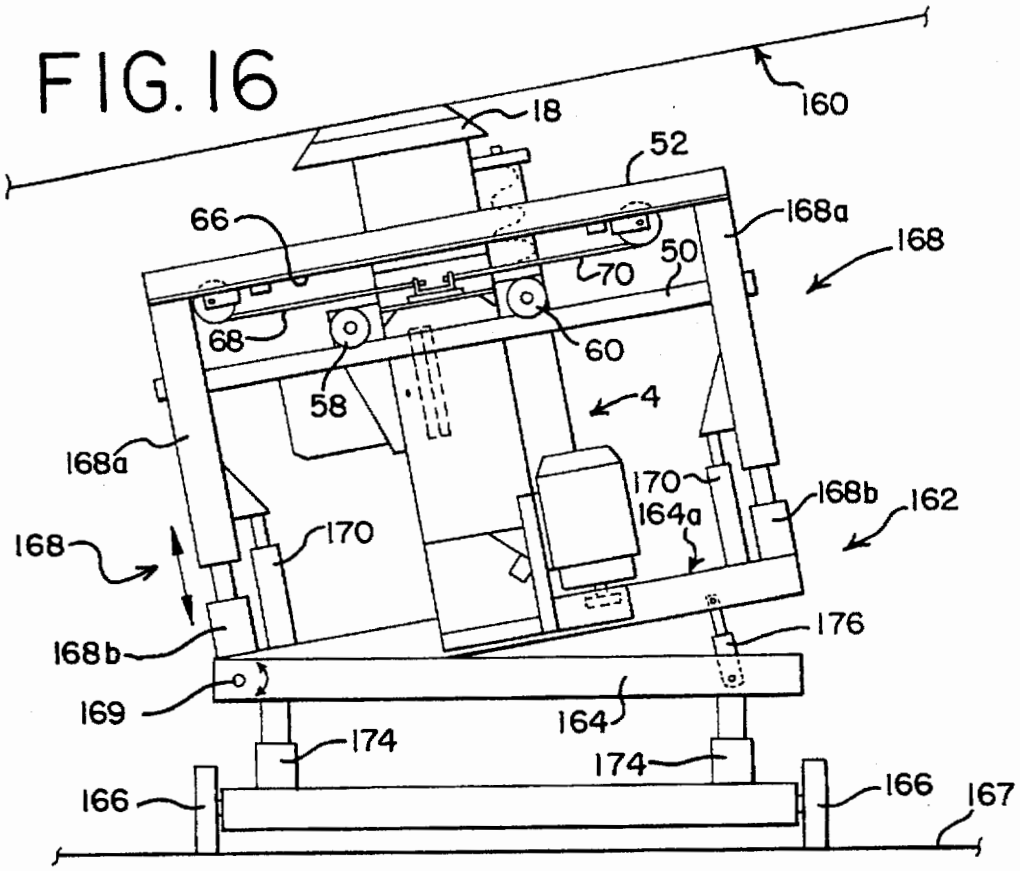
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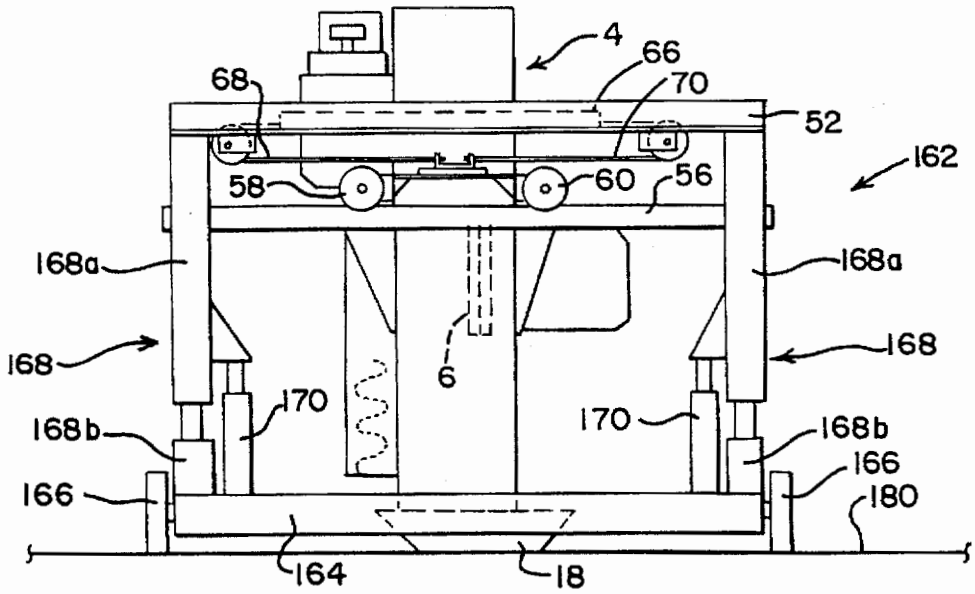
FIG. 17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168b
168b
166
166
180
164
18

OSCILLATING BLAST CLEANER

This application is a continuation of application Ser. No. 08/255,386, filed on Jun. 8, 1994, now abandoned, which is a continuation in part of Ser. No. 08/183,194 filed on Jan. 14, 1994, now abandoned.

BACKGROUND OF THE INVENTION

The invention relates, generally, to surface treating machines and, more particularly, to an improved blast machine for cleaning substantially vertical surfaces.

It is often necessary to clean or otherwise treat large substantially vertical surfaces such as ship hulls, large storage tanks and the like. Numerous efforts have been made in this area to design a machine that can be secured to these vertical surfaces in a manner that allows the machine to traverse the surface while cleaning or otherwise treating the surface. The problems inherent in supporting a large machine on a vertical surface, however, have caused these efforts to be mostly unsuccessful as these machines have been too large, cumbersome, expensive and inefficient to be commercially successful.

One problem associated with such devices is that the surfaces over which they must travel are not smooth, uniform surfaces. As will be appreciated, the surfaces of ship hulls and large storage tanks include projections and obstructions that prevent large machines from reaching corners, crevices and other hard to reach areas. Moreover, these projections may make it difficult for devices that rely on magnets or suction to adhere to the surface.

A second problem is encountered specifically with large storage tanks that are found at refineries, depots and other similar facilities and are used to store gasoline, oil and the like. It is necessary to periodically clean or otherwise treat the inside as well as the outside of these structures. Access to the interior of these structures, however, is limited to a substantially two foot diameter door. As a result, large machines, typically used to clean the exterior of these structures, cannot fit through the door such that the interior of the tanks must be cleaned by hand using a scaffold specifically designed for use in the interior of these tanks. As will be appreciated, the hand cleaning process is extremely slow and labor intensive and can be dangerous to those working on the inside of the tank.

Moreover, it will be appreciated that a typical blast wheel cleans a substantially rectangular area that is approximately the width of the blast wheel. At the upper and lower edges of the cleaned area the density of the shot impacting the surface is less than at the center portion of the cleaned area that is directly below the blast wheel. As a result, the upper and lower edges of the cleaned portion are not cleaned as thoroughly as the center portion. This phenomena is known as "fanning".

Because of the cleaning characteristics of a blast wheel, the traditional methods of moving a blast wheel over the surface produce undesirable results. For example, where the axis of rotation of the blast wheel is arranged perpendicular to the direction of travel, only a very narrow band (i.e., the approximate width of the blast wheel) of surface can be cleaned. Where the axis of rotation of the blast wheel is arranged parallel to the direction of travel of the blast wheel over the surface, a much wider band of surface can be cleaned; however, the edges of this band are "fanned" (i.e., not thoroughly blast cleaned). As a result, it is necessary to overlap adjacent bands extensively to achieve complete cleaning. As will be apparent, both of these situations are inefficient.

Thus, an improved surface treating apparatus that can efficiently clean large surfaces is desired.

SUMMARY OF THE INVENTION

The cleaning apparatus of the invention consists of a blast machine mounted on a support structure for oscillating motion relative thereto. In one embodiment, the blast machine consists of a blast wheel for projecting abrasive onto the surface, a hopper for collecting the spent abrasive and debris, a screw conveyor for returning the spent abrasive and debris to a separator where the debris is separated from the abrasive and the abrasive is returned to the blast wheel. The support structure is supported against the surface being cleaned on sleds or wheels. On a vertical surface the cleaning apparatus is raised by a winch and on a horizontal surface the wheels can be power driven. The blast machine is arranged with its axis of rotation perpendicular to the path of travel of the apparatus and is simultaneously oscillated relative to the support structure in a direction perpendicular to the path of travel of the support structure by a fluid cylinder and cable arrangement. As a result, the blast machine is able to clean or otherwise treat a path as wide as the range of oscillation with minimum overlap of adjacent paths. Finally, the components of the apparatus are designed to be removable such that the apparatus can be quickly and easily broken down to a size small enough to fit through small passages such as those found on storage tanks and the like.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a front view of one embodiment of the apparatus of the invention suspended on a vertical surface.

FIG. **2** is a side view of the apparatus of FIG. **1** suspended on a vertical surface.

FIG. **3** is a detailed side view showing the sealing arrangement of the invention.

FIGS. **4** and **5** are side views, showing the system for supporting the apparatus of FIG. **1** on a vertical surface.

FIG. **6** is a front view of an alternate embodiment of the invention.

FIGS. **7** and **8** are front and side views, respectively, showing an alternate system for supporting the apparatus of the invention.

FIG. **9** is a front view showing the system supported on a vertical surface by a boom.

FIGS. **10**, **11** and **12** are detailed views showing the support apparatus for use with a boom.

FIG. **13** is a side view showing the apparatus of the invention supported on a scaffold.

FIG. **14** is a front view of another embodiment of the apparatus of the invention.

FIG. **15** is a modification of the apparatus of FIG. **14**.

FIG. **16** is another modification of the apparatus of FIG. **14**.

FIG. **17** is another embodiment of a blast cleaning apparatus employing the principles of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring more particularly to FIGS. **1** and **2**, a preferred embodiment of the cleaning apparatus of the invention is shown generally at **1** suspended against a substantially vertical surface **2** such as a ship hull or storage tank. The cleaning apparatus **1** includes a blast unit **4** consisting of a

blast wheel **6** for projecting abrasive against surface **2**. Blast wheel **6** is rotated at high speed by electric motor **7** and projects the abrasive through a blast chamber formed in the blast machine housing **10** as will be understood by one skilled in the art.

A hopper **12** is mounted to the underside of housing **10** to collect the spent abrasive and debris after the abrasive impacts surface **2**. As will be appreciated, the abrasive strikes the surface **2** with sufficient kinetic energy to cause it to rebound from the surface and into hopper **12**.

To prevent the escape of abrasive and debris from the blast zone a seal arrangement is provided as best shown in FIGS. **2** and **3**. Specifically, four baffles **14** extend from housing **10** to define a rectangular chamber surrounding blast zone **16**. A resilient seal **18** is mounted over baffles **14** which contacts surface **2** to prevent the escape of abrasive and debris. Seal **18** consists of a square of flexible material secured to the baffles **14** at its periphery and having an aperture **20** formed centrally therein. Seal **18** contacts the surface **2** with aperture **20** disposed over the blast zone **16** such that the abrasive thrown by wheel **6** can contact the surface but the spent abrasive and debris are prevented from escaping the blast zone.

A second flexible seal **22** and third flexible seal **24** are mounted to baffles **26** and **28**, respectively, below and partially surrounding seal **18**. Seals **22** and **24** trap abrasive that may escape seal **18**. An additional flexible seal **30** is mounted on baffle **32** below seal **24** to collect any abrasive that may escape seals **22** and **24**. Holes **34** are formed in the housing to communicate the areas enclosed by the seals to the hopper **12** such that the abrasive collected by seals **18**, **22**, **24** and **30** will drain into hopper **12**. An additional baffle **36** and seal **38** are mounted inside of seal **18** above the blast zone to direct stray abrasive and debris downward toward holes **34**.

Referring again to FIGS. **1** and **2**, the blast unit further includes a screw conveyor **40** that is driven by motor **42**. Screw conveyor **40** removes the spent abrasive and debris from the hopper **12** and delivers it to separator **44**. Separator **44** can have any suitable construction that allows the abrasive to be separated from the debris and that delivers the abrasive back to wheel **6** as is known in the art.

A support structure or carriage **48** supports blast unit **4** on surface **2** and consists of a pair of side plates **50** connected by a cross member **52**. Each side plate **50** is supported on a sled **54** that rides on and slides over surface **2**. Each sled **54** includes a strip of high molecular weight plastic **55** that contacts and slides over surface **2**. Located on either side of strip **55** are permanent magnets **46**. Magnets **46** magnetically attract surface **2** to prevent the apparatus from swinging as it traverses the vertical surface.

When the apparatus reaches the end of its vertical path of travel, either at the top or bottom of surface **2**, the apparatus is moved horizontally as will hereinafter be described. Before it is moved horizontally, however, the magnets **46** must be removed from magnetic engagement with surface **2**. Accordingly, an air cylinder **47** is arranged on each sled **54** such that its reciprocating piston **49** extends perpendicularly to surface **2**. When piston **49** is retracted the apparatus will be arranged with the surface **2** in the solid line position (FIG. **2**) where sled **54** and seals **18**, **22**, **24** and **30** are in contact with the surface. In this position the blast cleaning operation is conducted. When plunger **49** is extended as shown in FIG. **2**, the apparatus is moved away from surface **2** such that there is a gap between the apparatus and surface **2**, shown in dashed line in FIG. **2**. In this position, the apparatus can be moved horizontally without resistance from the magnetic attraction between magnets **46** and surface **2**.

Also extending between side plates **50** is an elongated cylindrical rail **56**. Rail **56** supports the blast unit in a suspended manner via pulley wheels **58** and **60** that are freely rotatable in yokes **62** and **64** which, in turn, are fixed to the blast unit **4**. The pulley wheels **58** and **60** simply ride on rail **56** such that the blast unit **4** can be separated from support structure **48** merely by lifting wheels **58** and **60** from rail **56**.

Mounted to cross member **52** is the drive system for oscillating the blast unit **4** relative to the support structure **48**. The drive system consists of a fluid cylinder **66** fixed to cross member **52**. Flexible transmission members or cables **68** and **70** are reeved around pulleys **72** and **74** and are connected at their one end to the opposite sides of the movable piston (not shown) of cylinder **66** and at their opposite ends to flange **78** that is fixed to blast unit **4** via yokes **62** and **64**. As a result, when the piston of cylinder **66** is reciprocated by alternately pressurizing the chambers on opposite sides of the piston, the transmission members **68** and **70** will transmit the reciprocating motion to blast unit **4**. Such cable/cylinder drives are commercially available.

When cylinder **66** is activated, the blast unit **4** will be oscillated left and right as viewed in FIG. **1** as the wheels **58** and **60** ride on rail **56**. Switches **80** and **82** can be mounted on cross member **52** at any suitable position to be contacted by flange **78** thereby to control the pressurization of cylinder **66** and the width of the path traversed by the oscillating blast unit. While the cable/cylinder drive is shown, it is to be understood that other suitable oscillating drive mechanisms could be used if desired.

To raise and lower apparatus **1**, a winch **85** is mounted to the top of the apparatus. Specifically, a pair of bearing blocks **84** rotatably support shaft **86**. Shaft **86** is rotatably driven by variable speed reversible motor **88** and supports a pair of cable drums **90**. Cables **92** have their first ends connected to and reaved around drums **90** and have their opposite ends secured to the top of the surface being cleaned by any suitable support mechanism as will hereinafter be described. By actuating motor **88**, shaft **86** is rotated to wind and unwind cables **92** on cable drums **90** thereby to raise and lower the entire apparatus.

Referring to FIGS. **4** and **5**, a preferred support structure is illustrated for supporting the apparatus on a storage tank. The support structure includes a relatively small fixture **101** located on the top of the tank **102**. Fixture **101** includes four wheels **103** (two of which are shown) that ride on the top of tank **102**. Wheels **103** are driven by a hydraulic motor **105** or other suitable drive mechanism. The wheels **103** carry a support structure consisting of a horizontal arm **107** supporting a first vertical support **109** and a second vertical support **111**. A pair of support arms **113** are supported by vertical supports **109** and **111** (only one of which is visible in FIG. **4**) and has their ends **115** extending over the edge of the vertical surface and connected to the ends of cables **92** thereby to support apparatus **1** on surface **2**. The fixture **101** is dimensioned and constructed such that it counterbalances the weight of apparatus **1**. The position of vertical support **109** and support arm **113** can be made adjustable to accommodate vertical tanks or other structures having different configurations. Moreover, for tanks having different constructions the arrangement of fixture **101** can be modified so long as it is capable of traversing the surface and counterbalancing or supporting the weight of apparatus **1**.

The fixture **101** is supported on tank **102** by a tether arrangement. The typical storage tank includes a post **117**

mounted in the center thereof. A cable **119** connects arm **107** to the post **117**. Thus, when wheels **103** are driven by motor **105**, support **101** will circle about the periphery of tank **102** on tether **119**.

A cart **108** is positioned on the ground and carries the power and remote control system for controlling the fluid cylinder **66**, motor **42**, motor **88**, motor **7** and motor **105**. In the preferred embodiment, these drive mechanisms can be hydraulically operated where a compressor located on cart **108** drives all of the motors via hydraulic lines **110** or remotely controlled electric motors. It will be appreciated that other remote controlled drive systems can be used if desired.

Cart **108** can also carry a dust collector that is connected to separator **44** of apparatus **1** via hose **112**. Hose **112** pulls air through separator **44** to separate the abrasive from the debris in an air wash system as will be appreciated by one skilled in the art.

An alternate embodiment of apparatus **1** is illustrated in FIG. **6** where like numerals are used to identify like components of the preferred embodiment illustrated in FIG. **1**. Eliminated from the embodiment of FIG. **7** is the winch such that cables **92** are connected directly to side plates **50**. In this embodiment cables **92** are reaved around pulley wheel assemblies **114** supported on the top of ship hull or tank **102** on beam **116** as best shown in FIGS. **7** and **8**.

The opposite ends of cables **92** are connected to a winch **117** that is supported on the movable cart **108**. The cart **108** is weighted such that it is heavier than the apparatus **1** and can support the apparatus on the vertical surface **2**. The winch **117** is driven to slowly wind and unwind the cables **92** thereby to raise and lower the entire apparatus **1** over the surface **2**. The cart **108** also supports the controls for driving the various motors via hydraulic or electric lines as previously described with respect to FIGS. **4** and **5**.

As shown in FIGS. **7** and **8** beam **116** is supported on a relatively larger beam **118** on wheel assemblies **120** such that beam **116** can reciprocate relative to beam **118** in a horizontal direction. Beam **118** is supported on the top of the surface **2** by any suitable means such as fixture **101** as described with reference to FIGS. **4** and **5** or a boom arm as will hereinafter be described with reference to FIGS. **9** through **12**. A traction drive **122**, also controllable from the ground, moves beam **116** relative to beam **118**. As a result, the blast machine **1** can be moved laterally over surface **2** after each vertical pass of machine **1** by actuating drive **122**.

While in the illustrated embodiment beam **116** is supported by beam **118**, it is to be understood that beam **116** could be supported directly by fixture **101** (or other support mechanism) and beam **118** eliminated. With such a configuration beam **116** would be stationary and would be moved by support **101**, boom arm or other support after each vertical pass of machine **1**.

Another preferred support structure for the apparatus **1** will now be described with reference to FIGS. **9** through **12**. Beam **116** is shown supported adjacent surface **2** by a boom **124** mounted on truck **126**. While a boom is illustrated it will be appreciated that the apparatus **1** could be supported on a JLG or "spider" where the operator is situated in a cage located at the end of the boom arm at the top of the surface being cleaned. Any structure that can suspend the apparatus **1** from a position above the surface being cleaned can be used. Because the apparatus **1** is raised and lowered by cables **92** which are mounted to beam **116**, the beam **116** must be supported in a horizontal position regardless of the inclination of boom **124** in order to allow the machine to traverse the surface properly. When a JLG or spider is used as the support, the beam **116** is supported by the operator's cage and will be maintained in a horizontal orientation because the orientation of the cage is automatically maintained.

To maintain the horizontal orientation of beam **116** when a boom is used as the support, the support structure **128** is used. The support structure **128** includes a clamp **130** for fixing the support to the boom **124**. The clamp **130** consists of two plates **132**, **134** that surround the boom and are fixed together by fasteners such as bolts with the boom clamped therebetween. A pivot arm **138** is pivotally connected to plates **132**, **134** by pin **140** such that arm **138** can pivot about a horizontal axis relative to boom **124**.

The cable **142** of the boom arm is reaved around pulleys **144** at the end of boom **124** and is connected to arm **138**. The winding and unwinding of cable **142** will cause arm **138** to pivot relative to boom **124**. Thus, as the inclination of boom **124** changes, the arm **138** can be maintained in the illustrated horizontal position by winding or unwinding cable **142** as required.

Arm **138** carries the beam **116** that supports the blast machine. While in the illustrated embodiment arm **138** is supporting beam **116**, it will be appreciated that arm **138** could support beam **118** and beam **118** support beam **116** as described with reference to FIG. **7**. In either case the beam is supported on pin **140** such that it can pivot about a vertical axis relative to arm **138**. This pivoting motion allows the beam to be positioned substantially parallel to the surface being cleaned regardless of the angle at which the boom **124** approaches the surface. As a result, the beam will be oriented so as to suspend the machine as shown in FIG. **9**.

In another embodiment, the apparatus of FIG. **7** can be supported on the fixture **101** as illustrated in FIGS. **4** and **5**. In such an embodiment, the winch **85** is mounted on the end of support arm **113** rather than on apparatus **1**. The operation of the device will proceed as in the preferred embodiment except that vertical movement of the apparatus will be provided by the winch mounted to fixture **101**.

As the apparatus is raised, a vertical swath of surface **2** is cleaned that is as wide as the range of oscillation of blast machine **4** where the edges of the cleaned surface are clearly demarked without the effects of fanning. Once the apparatus reaches the top of surface **2**, support **101** is moved around the tank or beam **116** is moved along the surface **2** by a boom arm, JLG or other support mechanism a distance equal to the width of the cleaned strip and the apparatus is lowered. This process is repeated until the entire surface is cleaned.

The support structure **48** can be separated from the blast unit **4** by simply lifting pulley wheels **58** and **60** from rail **56** to break the apparatus down to a size where it can fit through the small door in the storage tank. Additionally, the drive motors **7** and **42** and the screw conveyor **40** and the bar magnets **46** can also be removed from the unit to further reduce its size if desired. The device can be quickly and easily reassembled on the interior of the tank.

Referring to FIG. **13**, to clean the interior of a storage tank, the cables **92** are suspended from the top of the scaffolding **150** that is presently used for hand cleaning the interior of the tank **102** such that the apparatus **1** rest against the inside wall **151**. The interior surface can then be cleaned by simply moving the scaffolding around the interior of the tank. It should be noted that the scaffolding support arrangement can be used on the exterior of the ship or tank as well as on the interior of the tank, if desired.

It will be appreciated that the winch for moving the apparatus vertically can be mounted on the apparatus as

shown in FIGS. **4** and **5**, on the fixture as shown in FIGS. **7** and **8** or on the support at the top of the surface being cleaned (not shown). Moreover, with the winch located in any one of these positions, the apparatus can be supported by the support of FIGS. **4** and **5**, the support beams of FIGS. **7** and **8**, the boom truck or JLG of FIG. **9** or any other suitable support. Moreover, the support beams of FIGS. **7** and **8** could be used with the support of FIGS. **4** and **5**, with the boom truck or JLG of FIG. **9** or with another support mechanism. Finally, the scaffolding shown in FIG. **13** can be used in place of the supports of FIGS. **4**, **5**, **7**, **8** and **9** with the winch mounted to the scaffolding, the apparatus **1** or the cart **108**. As will be appreciated, the support for the apparatus can have a variety of configurations provided it can move the apparatus vertically and horizontally over the surface. Moreover, carriage **48** could carry surface cleaning apparatuses other than the blast unit. For example, the blast unit could be replaced by scrubbing brushes or a painting unit if desired.

Referring more particularly to FIG. **14**, an alternate embodiment for supporting the blast unit **4** adjacent the underside of a horizontal surface **160** to be cleaned is shown. Surface **160** can be the underside of a ship hull or other similar horizontal surface. The blast unit **4** is constructed substantially the same as the blast unit previously described with reference to FIGS. **1** and **2** except that the blast wheel **6** is arranged to blast or project the abrasive vertically upward against surface **160** rather than horizontally against a vertical surface.

Blast unit **4** is supported for horizontal reciprocating movement in the same manner as the embodiment of FIGS. **1** and **2**. In summary, pulley wheels **58** and **60** ride on rail **56** to support blast unit **4**. A fluid cylinder **66** has its piston (not shown) connected to the blast unit **4** by cables **68** and **70**. This arrangement operates as previously described with reference to FIGS. **1** and **2** to reciprocate the blast unit **4** perpendicular to its direction of travel over surface **160**.

To support the blast unit **4** beneath surface **160**, the cable suspension system of the previously described embodiments is replaced by driven support cart **162**. Support cart **162** consists of a frame **164** supported on wheels **166** that ride on the ground, dry dock floor or other surface **167**. While only two wheels are shown, it is to be understood that frame **164** is preferably supported on four wheels. The wheels are driven by a suitable remote controlled hydraulic or electric motor such that the cart is driven below surface **160** in a direction perpendicular to the direction of oscillation of blast unit **4**.

Frame **164** supports posts **168** that in turn support rail **56** and cross member **52**. While only two posts are shown, it will be appreciated that four posts are preferred to provide a more stable structure. Each post **168** includes an upper section **168***a* and a lower section **168***b*. Sections **168***a* and **168***b* are slidable relative to one another such that the effective height of posts **168** can be changed. A biasing means is provided to adjust the height of posts **168** to maintain a predetermined pressure between the flexible seal **18** and the surface **160**. In a preferred embodiment a hydraulic cylinder **170** is connected between frame **164** and each upper post section **168***a* to vertically adjust the position of section **168***a* relative to section **168***b*. A proximity sensor **172** can be provided to control cylinders **170** to maintain a desired pressure between seal **18** and surface **160**. Other means such as a pneumatic cylinder, electric motor or similar device can be used if desired. It is further contemplated that a second set of cylinders **174** can be used to move the entire frame **164** vertically to provide gross adjustment and that cylinders **170** can be used to move the post sections **168***a* to provide fine adjustment as best shown in FIG. **15**.

Referring to FIG. **16**, a subassembly **164***a* of frame **164** that supports posts **168** can be made to pivot along an axis **169** arranged parallel to the direction of travel of the frame to orient the blast unit **4** at an angle relative to the horizontal. Such a pivoting arrangement will allow the machine to be used to clean the bottom of surfaces that are at an angle relative to the horizontal as shown such as are commonly found on the bottom of ship hulls. A fluid cylinder **176** or other similar driving mechanism can be used to pivot subassembly **164***a* relative to frame **164**.

In operation, wheels **166** are driven to move the entire apparatus along the length of surface **160**. As the apparatus traverses the surface, blast unit **4** is oscillated to clean a band of surface **160** as wide as the extent of oscillation of the blast unit.

Referring more particularly to FIG. **17**, an embodiment showing the blast cleaner of the invention arranged for cleaning a substantially horizontal surface **180** is shown. Surface **180** can be at an angle relative to horizontal provided that the blast machine can traverse the surface. Blast unit **4** is constructed similarly to the blast unit previously described with reference to FIGS. **1** and **2** except that blast wheel **6** is arranged to project abrasive downward against surface **180**.

Blast unit **4** is supported for horizontal reciprocating movement in substantially the same manner as the embodiment of FIGS. **1** and **2**. In summary, pulley wheels **58** and **60** ride on rail **56** to support blast unit **4**. A fluid cylinder **66** has its piston (not shown) connect to blast unit **4** by cables **68** and **70**. This arrangement operates as previously described to reciprocate blast unit **4** perpendicular to its direction of travel over surface **180**.

To support the blast unit **4** on surface **180**, the support cart **162** as previously described with reference to FIG. **14** is used, where like reference numerals are used in FIG. **17** to identify like components previously described with reference to FIG. **14**. Support cart **162** consists of a frame **164** supported on wheels **166** that ride on the ground, dry dock floor or other surface **167**. While only two wheels are shown, it is to be understood that frame **164** is preferably supported on four wheels. The wheels are driven by a suitable remote controlled hydraulic or electric motor such that the cart is driven below surface **160** in a direction perpendicular to the direction of oscillation of blast unit **4**.

Frame **164** supports posts **168** that in turn support rail **56** and cross member **52**. While only two posts are shown, it will be appreciated that four posts are preferred to provide a more stable structure. Each post **168** includes an upper section **168***a* and a lower section **168***b*. Sections **168***a* and **168***b* are slidable relative to one another such that the effective height of posts **168** can be changed. A biasing means is provided to adjust the height of posts **168** to maintain a predetermined pressure between the flexible seal **18** and the surface **160**. In a preferred embodiment a hydraulic cylinder **170** is connected between frame **164** and each upper post section **168***a* to vertically adjust the position of section **168***a* relative to section **168***b*. A proximity sensor **172** can be provided to control cylinders **170** to maintain a desired pressure between seals **172** and surface **16***a*. Other means such as a pneumatic cylinder, electric motor or similar device can be used if desired.

In the blast cleaning apparatus of the invention, the axis of rotation of the blast wheel is arranged perpendicular to the direction of travel of the apparatus over the surface and

parallel to the direction of oscillation. Such an orientation of the blast wheel in combination with the oscillating movement of the blast unit creates a sharp line of demarcation between the cleaned area of the surface and the uncleaned area. As a result, minimal overlap of adjacent passes of the blast unit is required and a more efficient cleaning process results. Moreover, the blast cleaning apparatus of the invention, due to the oscillation of the unit, cleans a wide path of surface when compared to the size of the blast wheel. Thus, a surface treated with the oscillating blast machine of the invention is efficiently cleaned or treated uniformly over the entire surface.

While the invention has been described in some detail with respect to the drawings, it will be appreciated that numerous changes in the details and construction of the invention can be made without departing from the spirit and scope of the invention.

What is claimed is:

1. An apparatus for cleaning a horizontal or inclined surface comprising:

a) blast means for delivering cleaning material to the surface;

b) a housing for containing the blast means; and

c) a carriage for supporting the housing, the carriage being movable in a first, generally horizontal direction;

d) a support rail for supporting the housing for traversing movement in a second direction, substantially perpendicular to the first direction, with respect to the carriage;

e) means for reciprocating the housing on the support rail; and

f) means for adjusting the orientation of the support rail such that the angle of the support rail and the traversing movement of the housing, relative to the horizontal, may be adjusted to permit cleaning of the inclined surface.

2. The apparatus of claim **1**, wherein the means for adjusting comprises at least one fluid cylinder connected between the support rail and the carriage such that the support rail may be angled with respect to the horizontal.

3. The apparatus of claim **1**, wherein the housing further comprises a seal for engaging the surface, and means for sensing the proximity of the housing to the surface, the means for sensing cooperating with the means for adjusting to maintain a desired pressure between the seal and the surface.

4. The apparatus of claim **1**, wherein the housing is provided with at least one roller for engaging the rail member.

5. The apparatus of claim **4**, wherein the roller is provided with a surface shaped for engaging the rail member.

6. The apparatus of claim **5**, wherein the support rail is round in cross-section and the roller is provided with a shape for complementarily receiving the rail member.

7. An apparatus for blast cleaning a horizontal or inclined surface while traveling across a ground area underneath the horizontal or inclined surface, the apparatus comprising:

a) a blast wheel for delivering cleaning material to the surface;

b) a housing for containing the blast wheel;

c) frame having a plurality of wheels for traveling across the ground area;

d) rail member for supporting the housing for movement on the frame;

e) means for reciprocating the housing on the rail member; and

f) means for adjusting the orientation of the rail member, whereby the rail member may be adjusted to permit the housing to traverse along the inclined surface.

8. The apparatus of claim **7**, wherein the means for adjusting comprises at least one fluid cylinder connected between the rail member and the frame such that the rail member may be angled with respect to the frame.

9. The apparatus of claim **7**, wherein the housing further comprises a seal for engaging the surface, and means for sensing the proximity of the housing to the surface, the means for sensing cooperating with the means for adjusting to maintain a desired pressure between the seal and the surface.

10. The apparatus of claim **7**, wherein the housing is provided with at least one roller for engaging the rail member.

11. The apparatus of claim **10**, wherein the roller is provided with a surface shaped for engaging the rail member.

12. The apparatus of claim **11**, wherein the rail member is round in cross-section and the roller is provided with a shape for complementarily receiving the rail member.

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