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WILKES

(54) **APPARATUS ADAPTED FOR THE REMOVAL OF FOREIGN MATTER**

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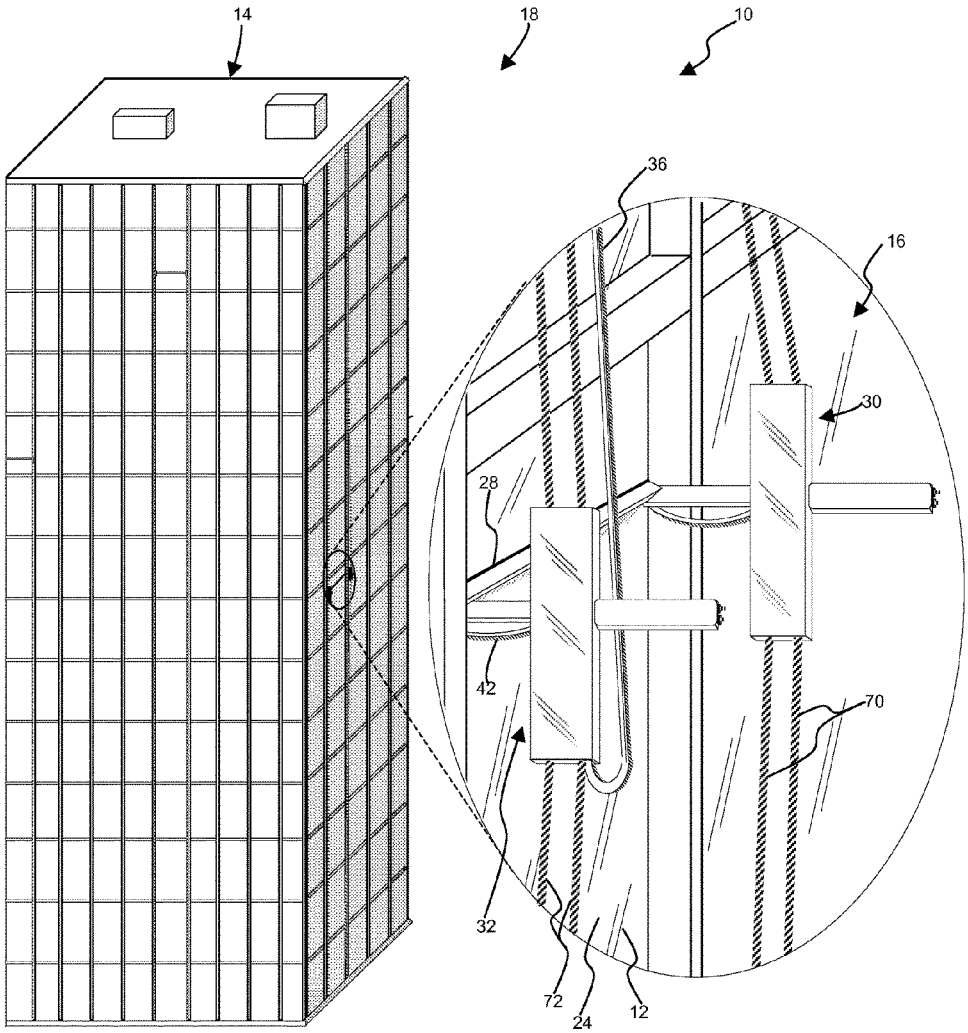
(57) **ABSTRACT**

An apparatus adapted for the removal of foreign matter from the exterior of windows of a building can include a cleaning unit and a positioning unit. The cleaning unit can extend a depth between a front side confronting the work surface and a back side opposite the front side. The cleaning unit can include a cleaning agency. The positioning unit can be engaged with the cleaning unit to move the cleaning unit among a plurality of different positions relative to the building.



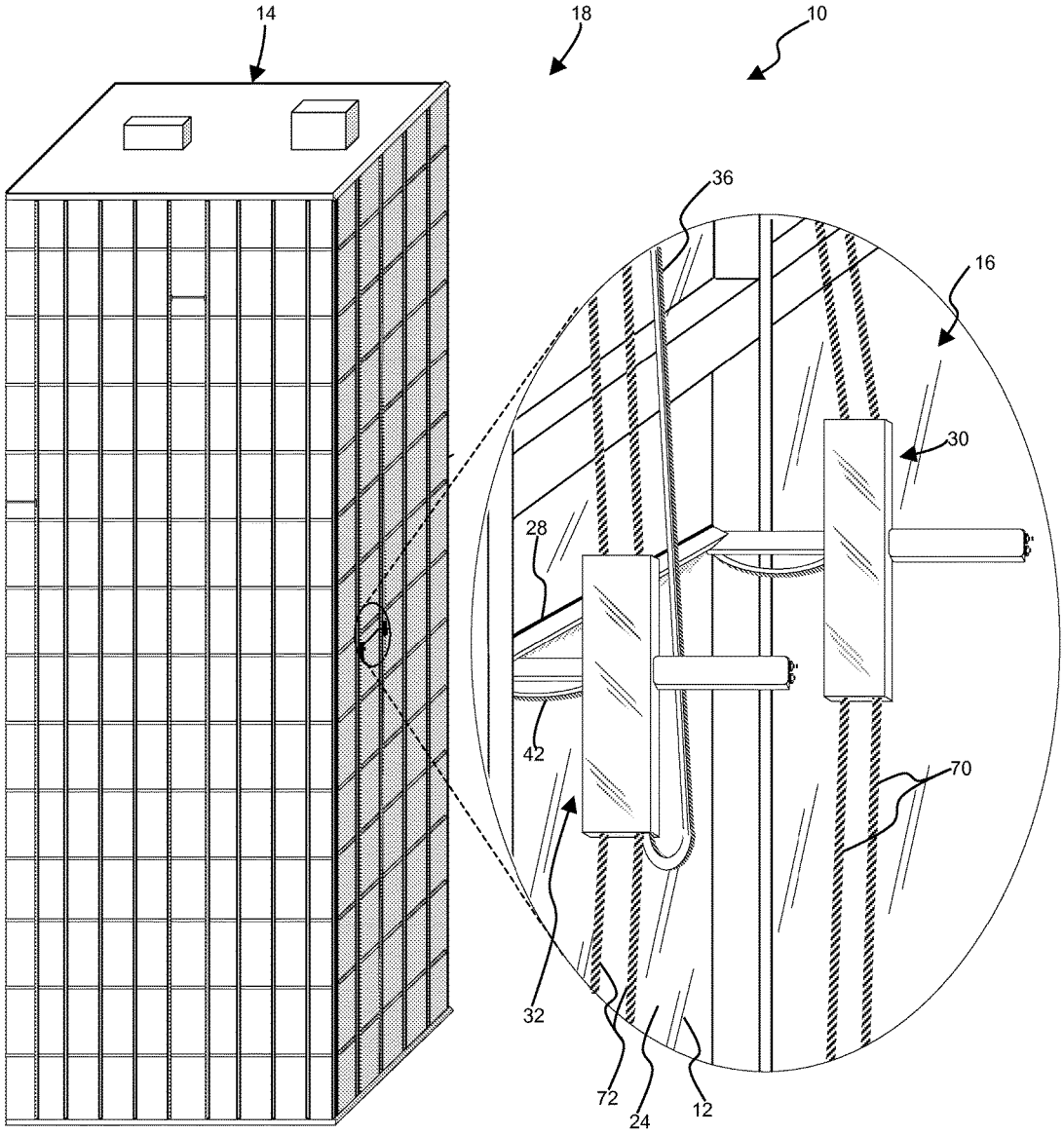
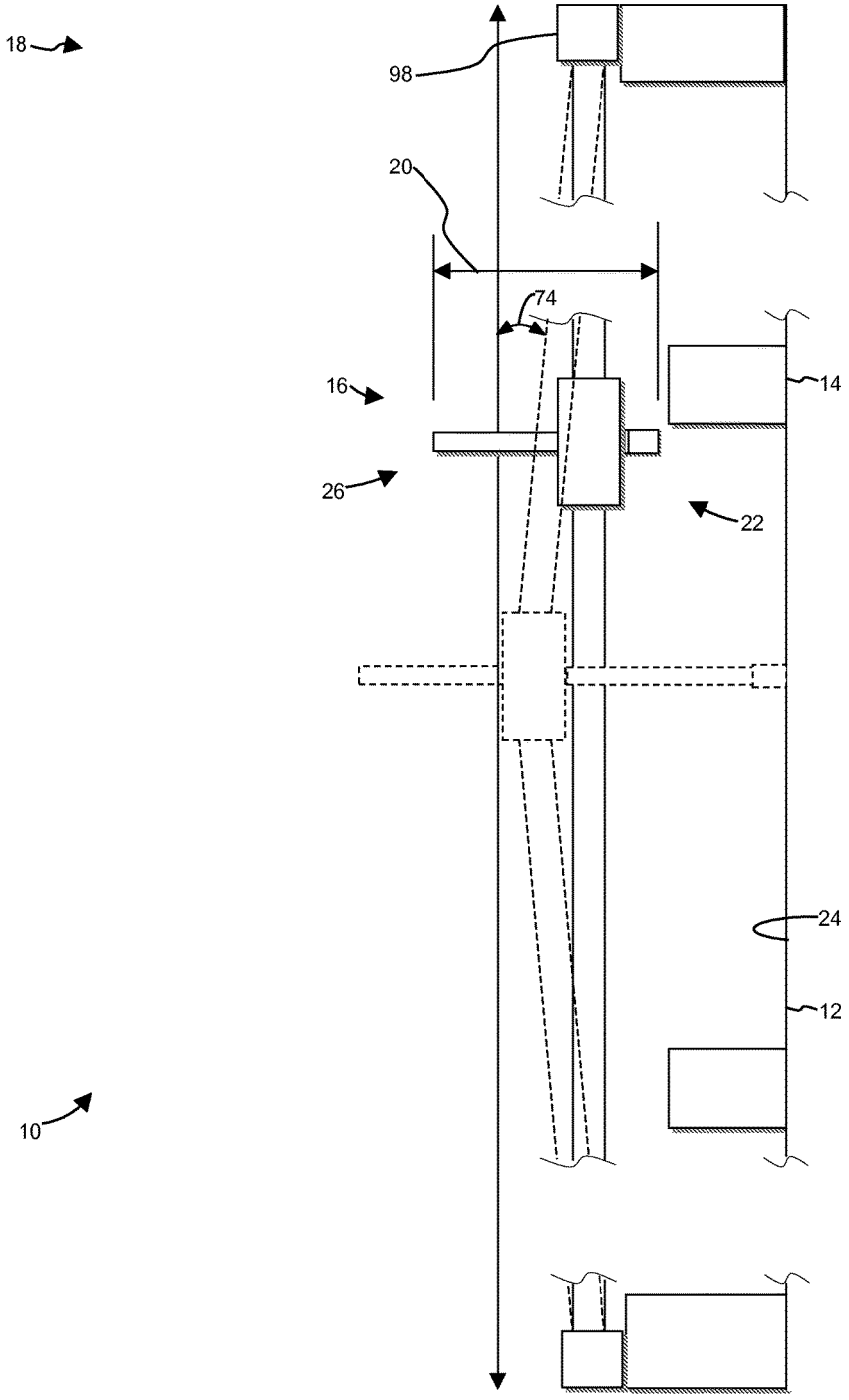


FIGURE 1

FIGURE 2



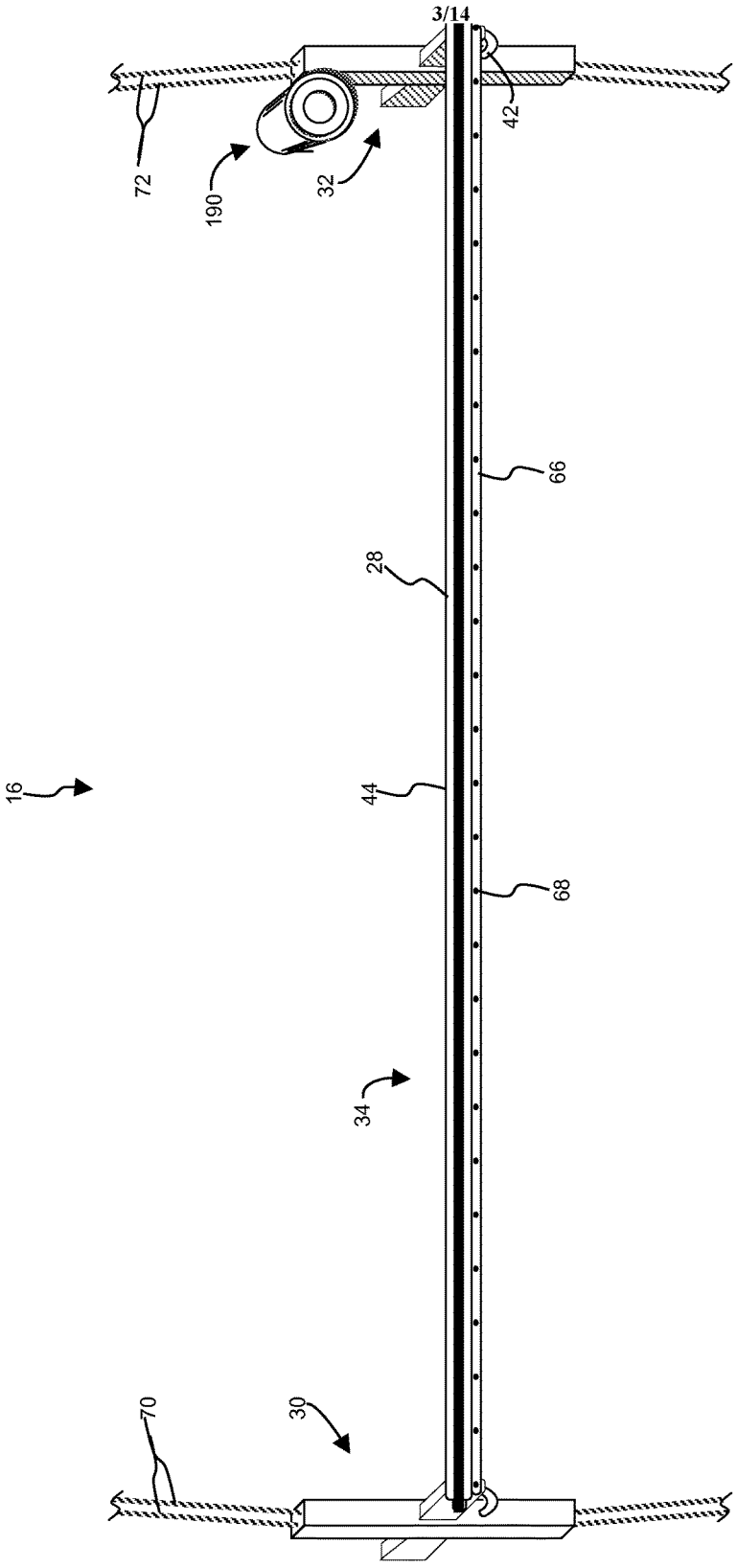


FIGURE 3

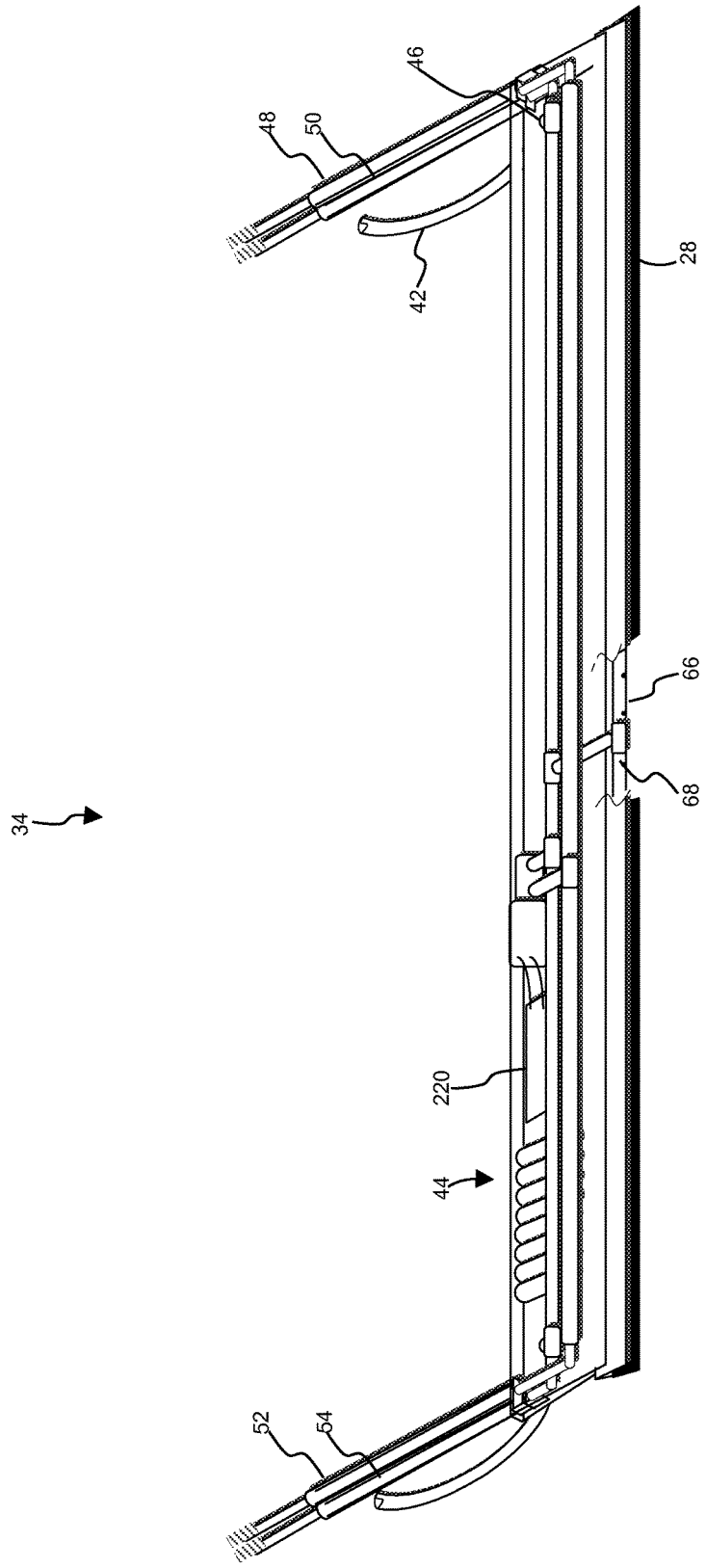


FIGURE 4

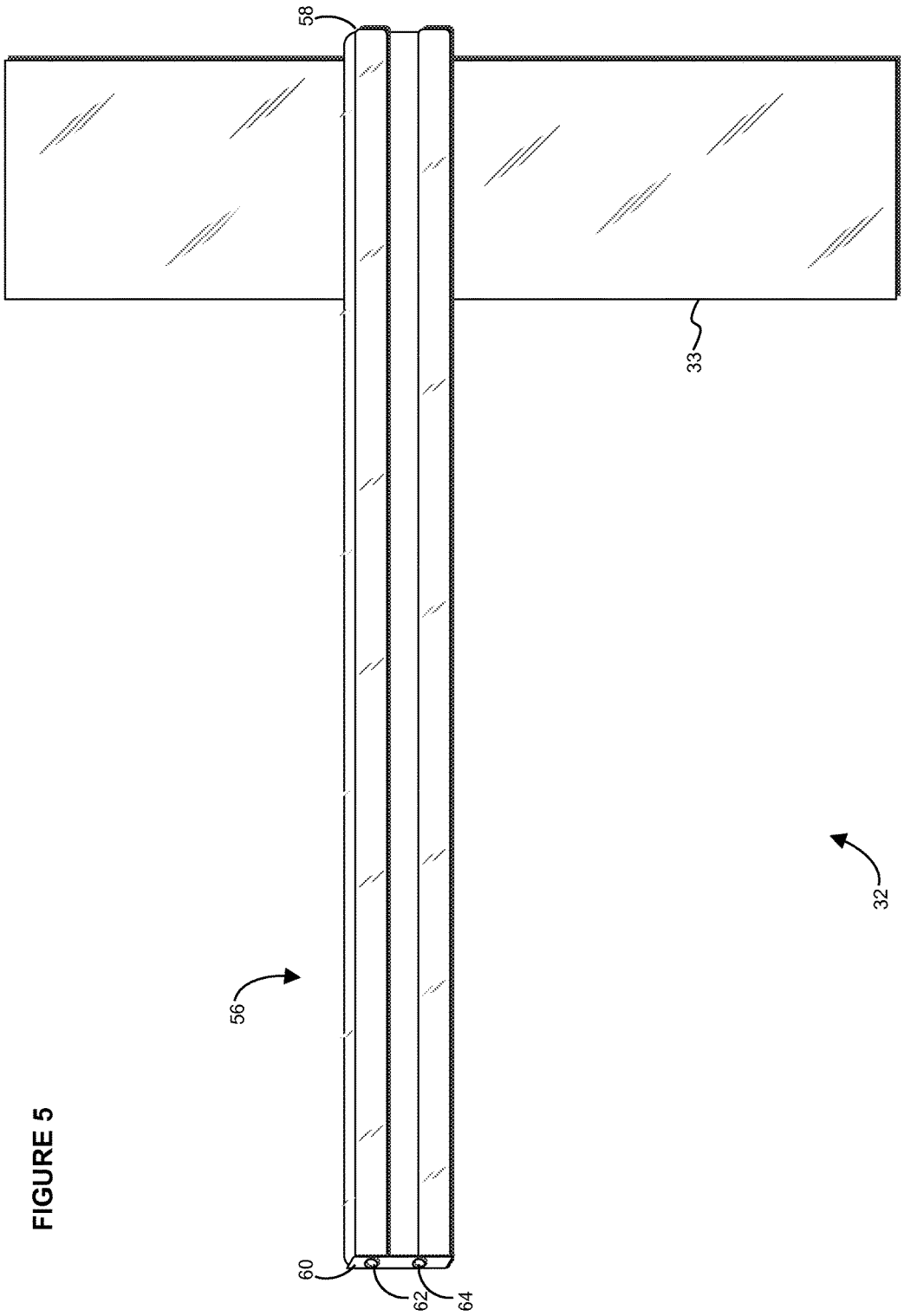
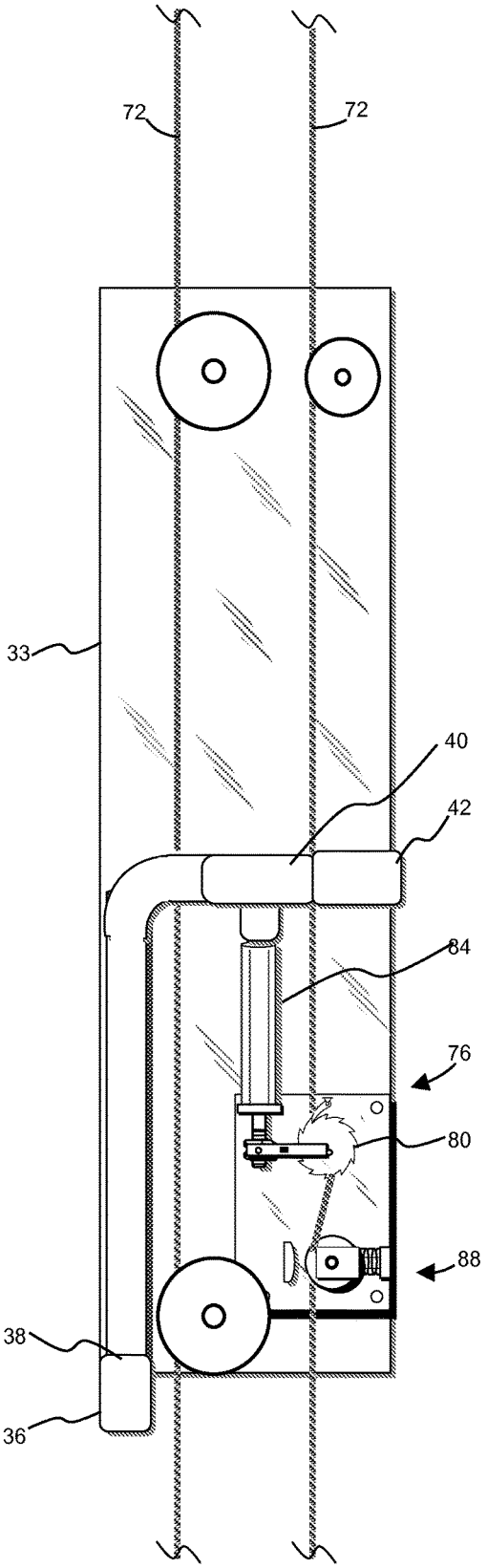


FIGURE 5

FIGURE 6



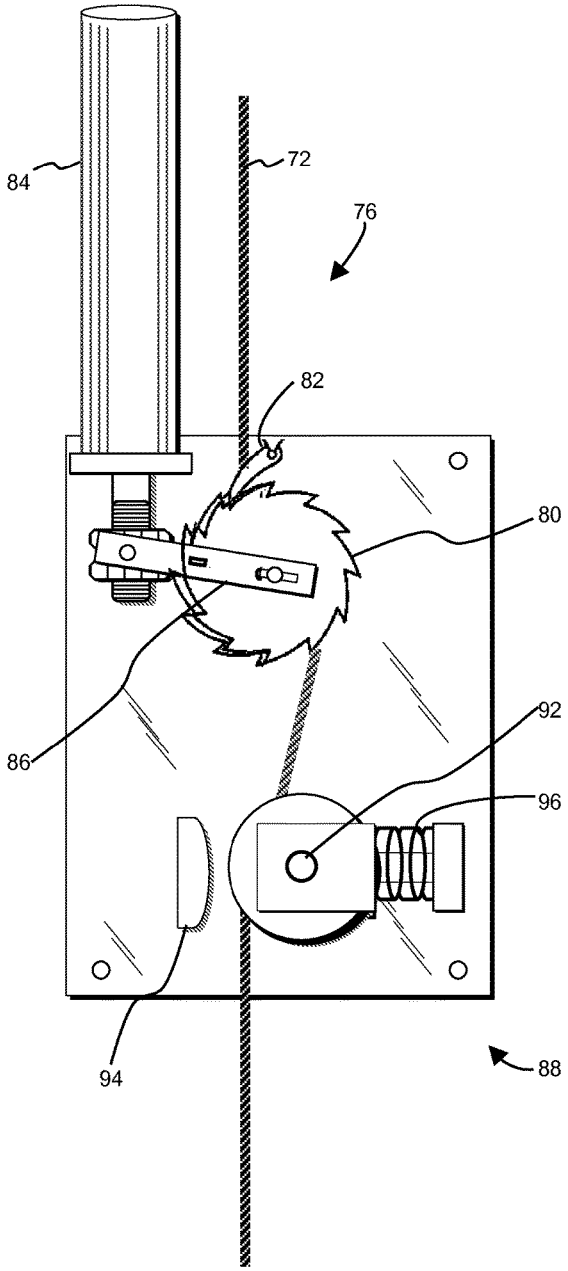


FIGURE 7

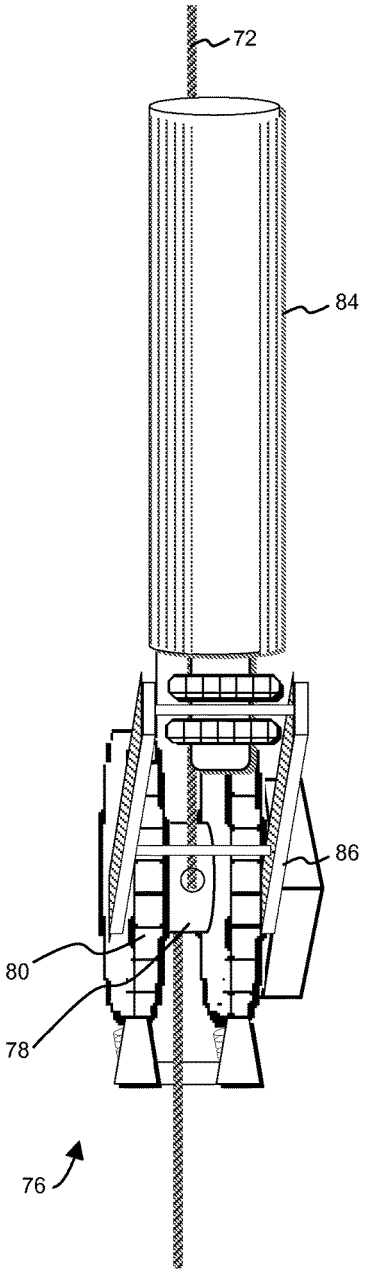


FIGURE 8

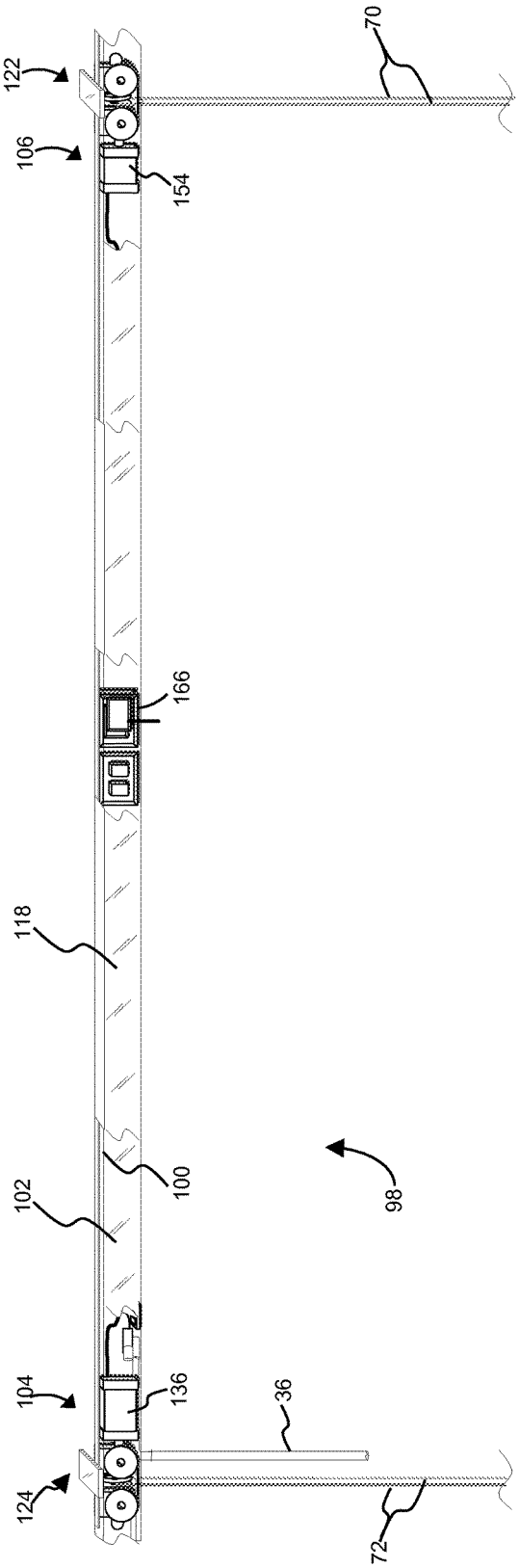


FIGURE 9

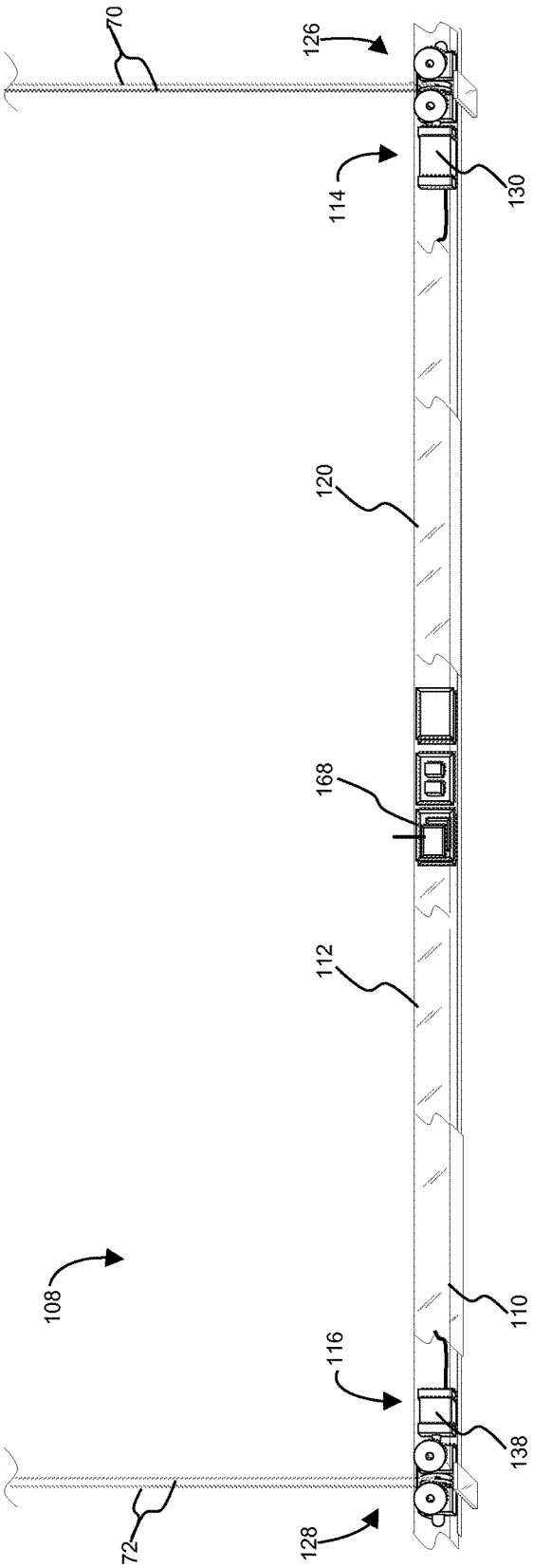


FIGURE 10

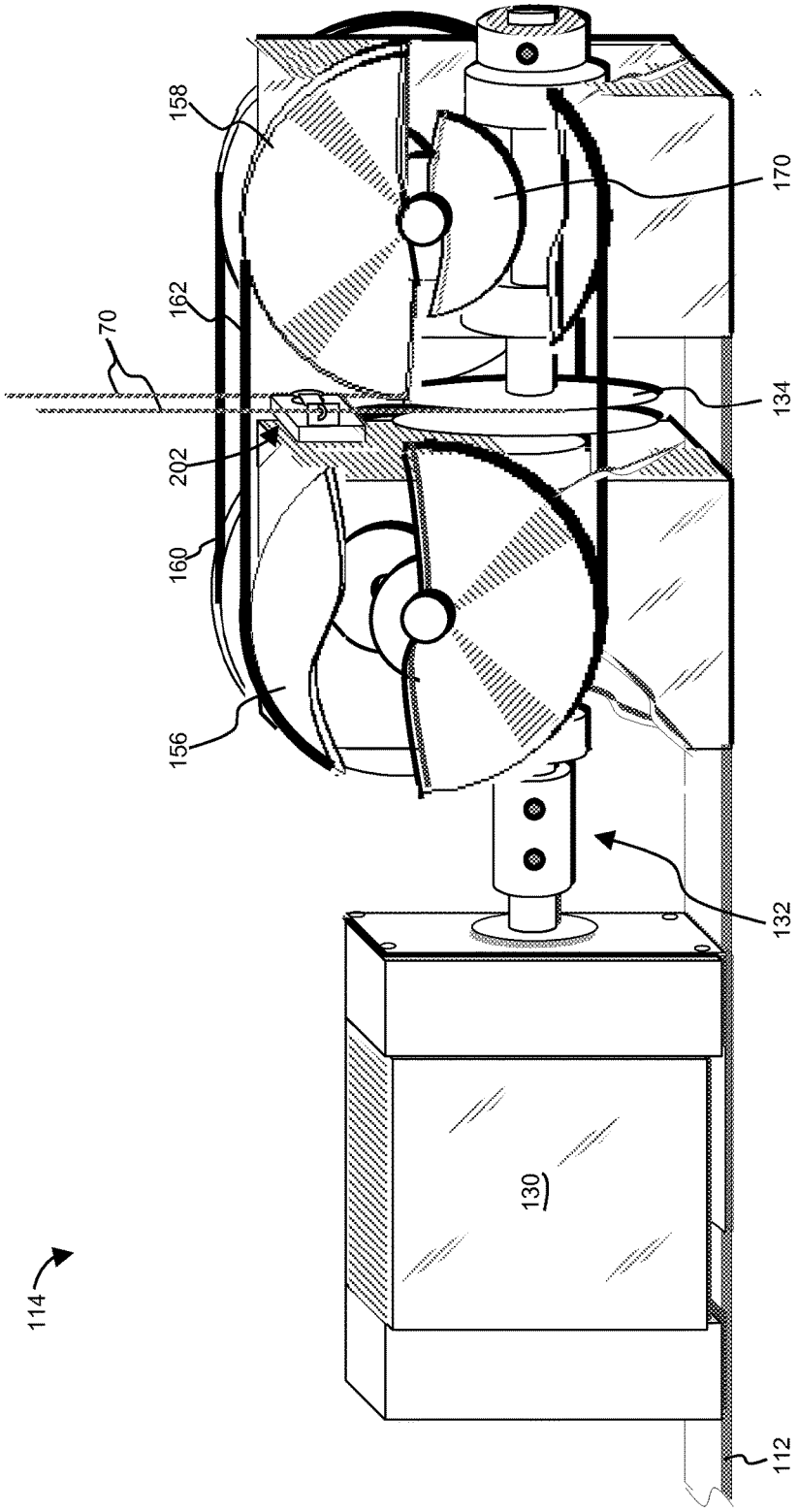


FIGURE 11

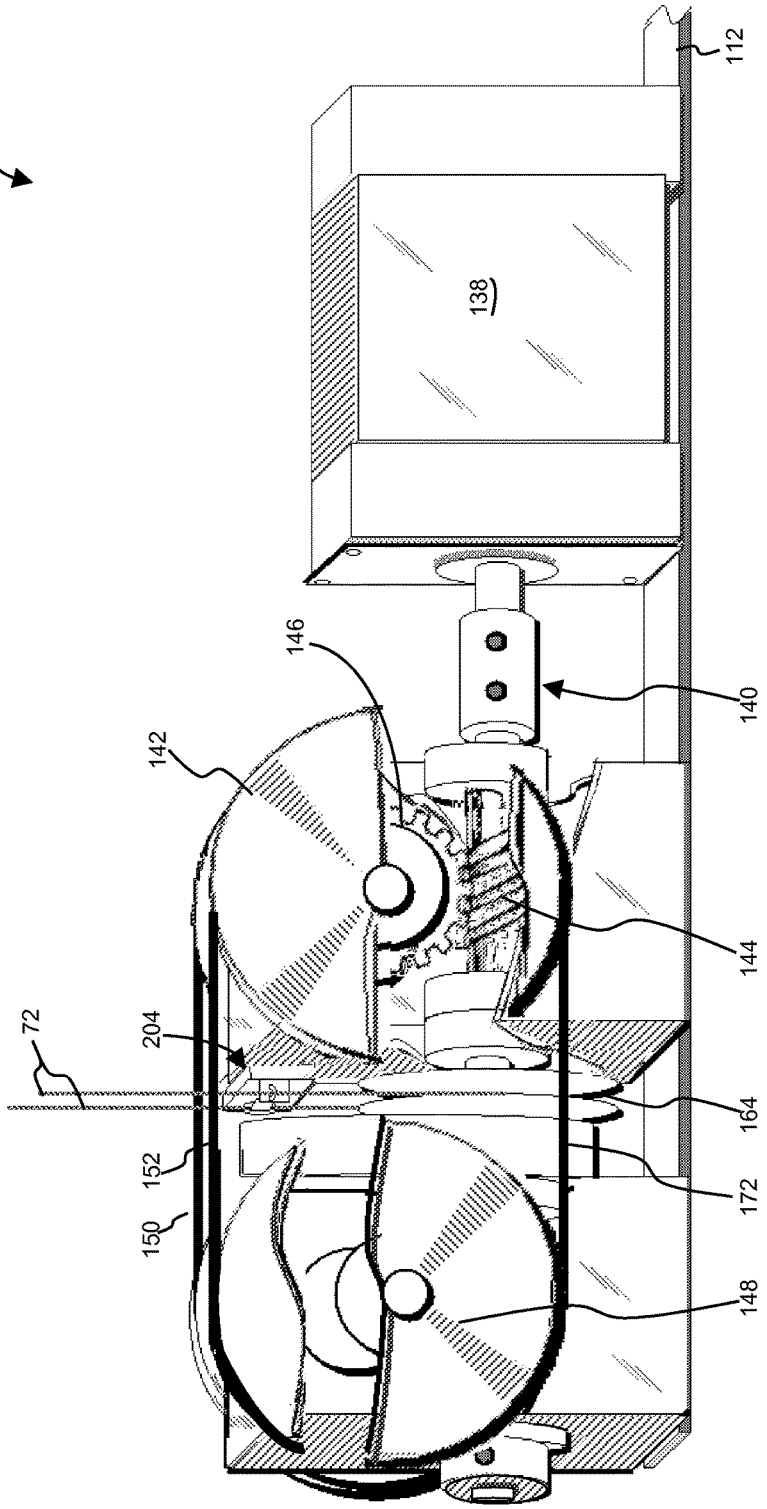
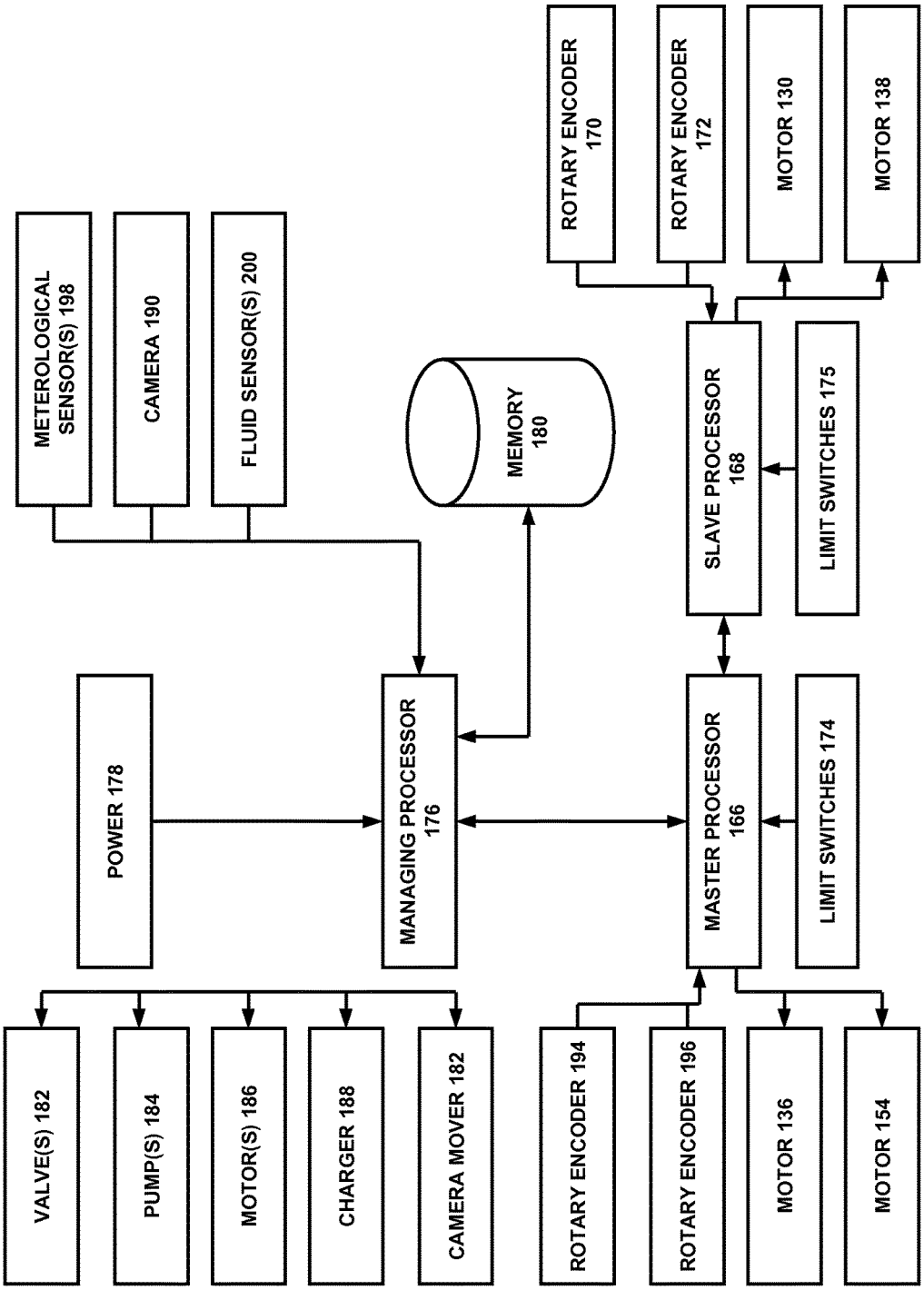


FIGURE 12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FLUID SENSOR(S) 200
ROTARY ENCODER 170
ROTARY ENCODER 172
MOTOR 130
MOTOR 138
MEMORY 180
SLAVE PROCESSOR 168
LIMIT SWITCHES 175
POWER 178
MANAGING PROCESSOR 176
MASTER PROCESSOR 166
LIMIT SWITCHES 174
VALVE(S) 182
PUMP(S) 184
MOTOR(S) 186
CHARGER 188
CAMERA MOVER 182
ROTARY ENCODER 194
ROTARY ENCODER 196
MOTOR 136
MOTOR 154

FIGURE 13

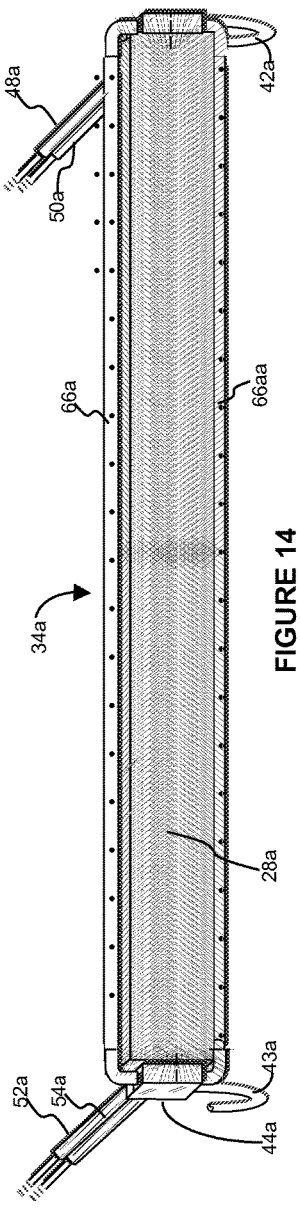

FIGURE 14

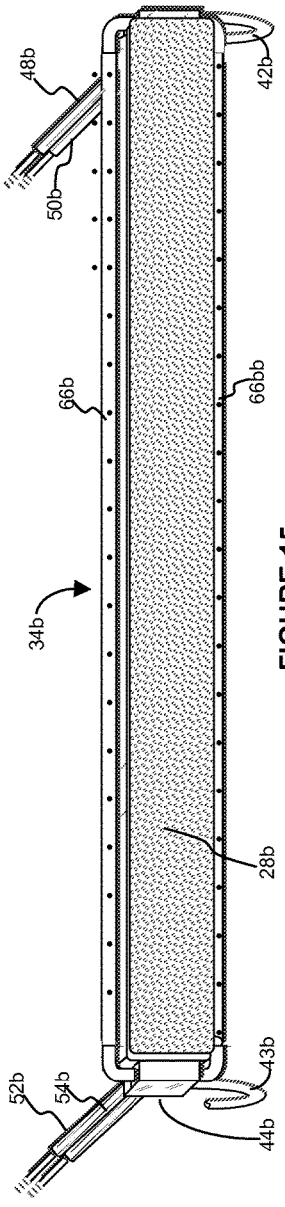

FIGURE 15

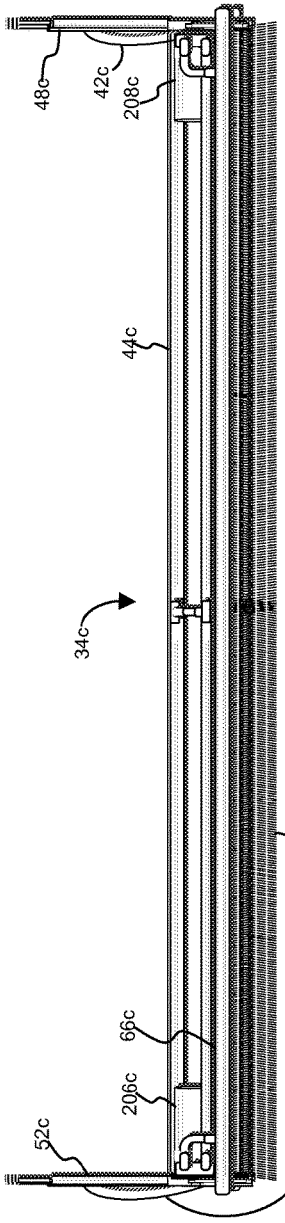

FIGURE 16

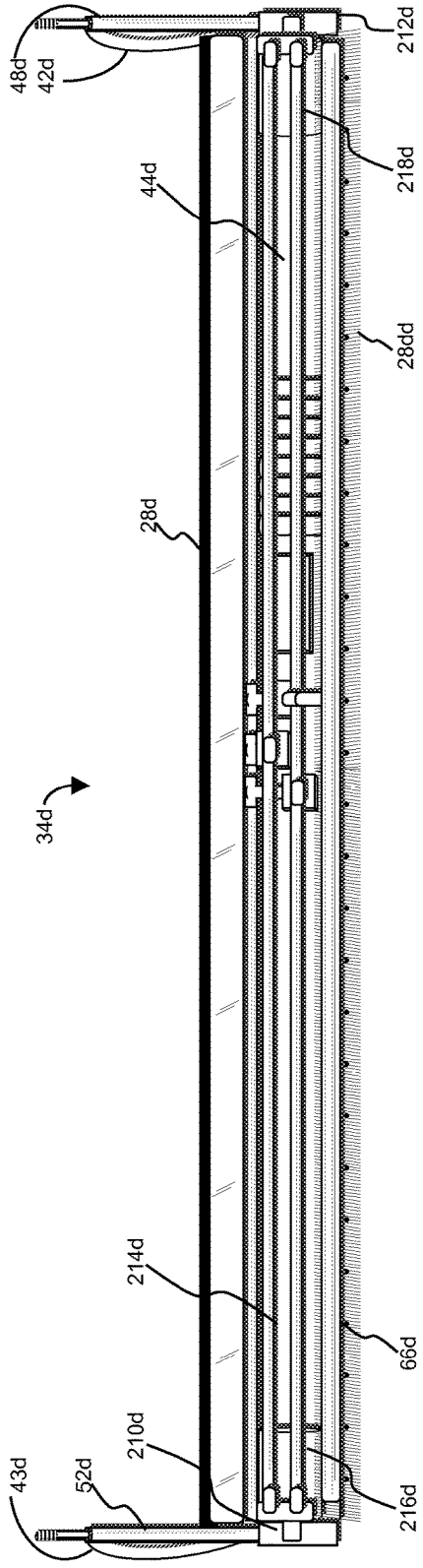

FIGURE 17

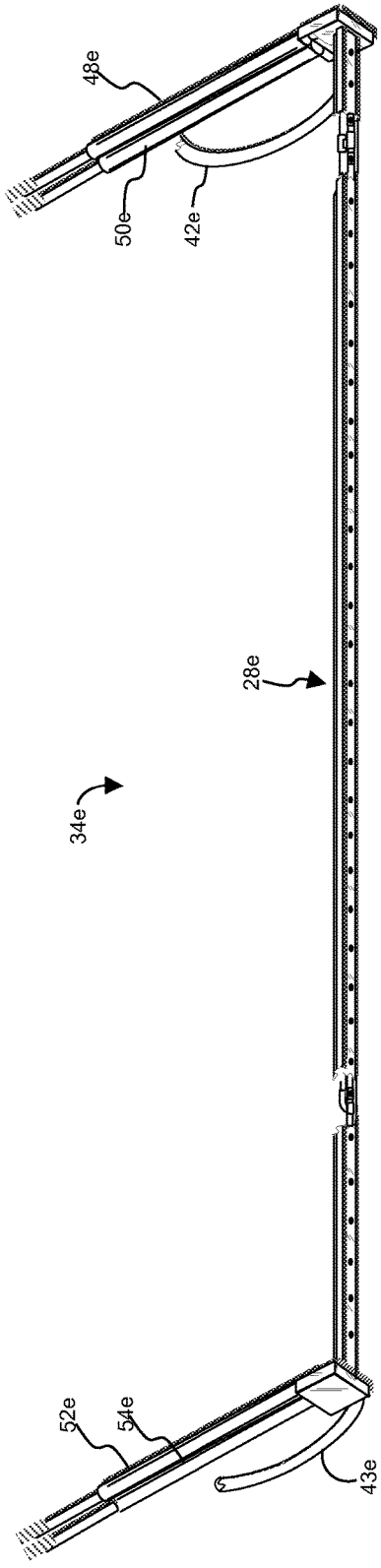

FIGURE 18

APPARATUS ADAPTED FOR THE REMOVAL OF FOREIGN MATTER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application Ser. No. 62/024,477 for a HIGH-RISE WINDOW CLEANING SYSTEM, filed on Jul. 15, 2014, which is hereby incorporated by reference in its entirety.

BACKGROUND

[0002] 1. Field

[0003] The present disclosure relates to an apparatus adapted for the removal of foreign matter and which contains within itself its own guide for operation to move a cleaning agency relative to a work surface, such as classified in USPC Class Number 15.

[0004] 2. Description of Related Prior Art

[0005] U.S. Pub. No. 20130081652 discloses an Apparatus and Method for cleaning Facades on multi-story buildings. That document relates to an automatic cleaning apparatus (1) for cleaning facades on multi-story buildings. The apparatus comprises a rotating brush (11) arranged rotatable about its longitudinal axis, a drive mechanism (16) for rotating the brush, a container (18) for housing a cleaning fluid, and a fluid feeding device adapted to feed the rotating brush with cleaning fluid from the container by means of capillarity forces. The apparatus is designed to engage to steering guides (4) provided on the facade. The apparatus is designed so that a downward movement of the apparatus is solely powered by gravity forces acting on the apparatus. The drive mechanism for rotating the brush comprises at least one drive wheel (16) arranged to be in contact with the surface of the facade and to generate a friction powered torque during downward movement of the cleaning apparatus, and a transmission unit arranged to transfer the torque of the drive wheel to the rotating brush to make the brush rotate during the downward movement. The apparatus further comprises a wiper device (22) arranged above the rotating brush and adapted to be in contact with the facade during cleaning to wipe off used cleaning fluid from the facade, and a fluid collecting member arranged to collect the cleaning fluid wiped off by the wiper device, and to transport the collected cleaning fluid to the container for reuse.

[0006] The background description provided herein is for the purpose of generally presenting the context of the disclosure. Work of the presently named inventors, to the extent it is described in this background section, as well as aspects of the description that may not otherwise qualify as prior art at the time of filing, are neither expressly nor impliedly admitted as prior art against the present disclosure.

SUMMARY

[0007] An apparatus adapted for the removal of foreign matter from the exterior of windows of a building can include a cleaning unit and a positioning unit. The cleaning unit can extend a depth between a front side confronting the work surface and a back side opposite the front side. The cleaning unit can include a cleaning agency. The positioning unit can be engaged with the cleaning unit to move the cleaning unit among a plurality of different positions relative to the building.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The detailed description set forth below references the following drawings:

[0009] FIG. **1** is a perspective view of an exemplary embodiment of the present disclosure positioned to remove foreign matter from exterior windows of a building;

[0010] FIG. **2** is a schematic side view of an exemplary embodiment of the present disclosure disposed to move vertically between floors of a building;

[0011] FIG. **3** is a perspective view of a front side of a cleaning unit according to an exemplary embodiment of the present disclosure;

[0012] FIG. **4** is a perspective view of a front side of a cleaning attachment assembly of a cleaning unit according to an exemplary embodiment of the present disclosure with an outer housing being transparent to reveal internal structures;

[0013] FIG. **5** is a side view of a truck of a cleaning unit according to an exemplary embodiment of the present disclosure with portions cut away to reveal internal structures, wherein the side of the truck illustrated is an internal side;

[0014] FIG. **6** is a side view of a truck of a cleaning unit according to an exemplary embodiment of the present disclosure with portions cut away to reveal internal structures, wherein the side of the truck illustrated is an external side;

[0015] FIG. **7** is a magnified portion of FIG. **6** illustrating a side view of a tensioning unit and a braking unit of a cleaning unit according to an exemplary embodiment of the present disclosure;

[0016] FIG. **8** is a left-hand view of the structures shown in FIG. **7**;

[0017] FIG. **9** is a perspective view of an upper positioning assembly of a positioning unit according to an exemplary embodiment of the present disclosure;

[0018] FIG. **10** is a perspective view of a lower positioning assembly of a positioning unit according to an exemplary embodiment of the present disclosure;

[0019] FIG. **11** is a perspective view of a vertical adjustment assembly of an upper positioning assembly according to an exemplary embodiment of the present disclosure;

[0020] FIG. **12** is a perspective view of a lateral adjustment assembly of an upper positioning assembly according to an exemplary embodiment of the present disclosure;

[0021] FIG. **13** is a schematic view of a control system according to an exemplary embodiment of the present disclosure;

[0022] FIG. **14** is a perspective view of a first alternative cleaning attachment assembly according to an exemplary embodiment of the present disclosure;

[0023] FIG. **15** is a perspective view of a second alternative cleaning attachment assembly according to an exemplary embodiment of the present disclosure;

[0024] FIG. **16** is a perspective view of a third alternative cleaning attachment assembly according to an exemplary embodiment of the present disclosure;

[0025] FIG. **17** is a perspective view of a fourth alternative cleaning attachment assembly according to an exemplary embodiment of the present disclosure; and

[0026] FIG. **18** is a perspective view of a fifth alternative cleaning attachment assembly according to an exemplary embodiment of the present disclosure.

DETAILED DESCRIPTION

[0027] A plurality of different embodiments of the present disclosure is shown in the Figures of the application. Similar features are shown in the various embodiments of the present disclosure. Similar features across different embodiments have been numbered with a common reference numeral and have been differentiated by a singular or double alphabetic suffix. Also, to enhance consistency, the structures in any particular drawing share the same alphabetic suffix even if a particular feature is shown in less than all embodiments. Similar features are structured similarly, operate similarly, and/or have the same function unless otherwise indicated by the drawings or this specification. Furthermore, particular features of one embodiment can replace corresponding features in another embodiment or can supplement other embodiments unless otherwise indicated by the drawings or this specification.

[0028] Referring now to FIG. **1**, an apparatus **10** adapted for the removal of foreign matter from the exterior of windows of a building **14**, such as window **12**, can include a cleaning unit **16** and a positioning unit **18**. Referring now to FIG. **2**, the cleaning unit **16** can extend a depth **20** between a front side **22** confronting a work surface, such as the surface **24** of the window **12**, and a back side **26** opposite the front side **22**. Referring now to FIG. **3**, the cleaning unit **16** can include a cleaning agency **28**. In FIG. **3**, the exemplary cleaning agency **28** can be a wiper blade. Referring again to FIG. **2**, the positioning unit **18** can be engaged with the cleaning unit **16** to move the cleaning unit **16** among a plurality of different positions relative to the building **14**. Each of the plurality of different positions can be defined by different windows of the building **14**.

[0029] A cleaning agency is a structure or mechanism for cleaning. A cleaning agency can be a flow of air, steam, or equivalent gaseous fluid; liquid fluid; a brush; a pad; a scraper or blade (squeegee), or any combination having one or more of these agencies. Embodiments of the present disclosure can be practiced with any form of these cleaning agencies.

[0030] Referring again to FIG. **3**, the exemplary cleaning unit **16** can include a first truck assembly **30**, a second truck assembly **32**, and a cleaning attachment assembly **34**. As will be described in greater detail below, the first truck assembly **30** and the second truck assembly **32** can couple the cleaning attachment assembly **34** to the positioning unit **18**. As will be described in greater detail below, the first truck assembly **30** and the second truck assembly **32** can each be engaged with cleaning attachment assembly **34** whereby at least a portion of the cleaning attachment assembly **34** can move relative to the first truck assembly **30** and the second truck assembly **32**. The cleaning agency **28** can be mounted on the cleaning attachment assembly **34**.

[0031] Fluid, such as fluid at high pressure, can be directed to the cleaning unit **16**. The pressure of the fluid directed to the cleaning unit **16** can be any desired pressure, such as from eighty pounds per square inch (PSI) to five thousand PSI. The fluid can be directed to the cleaning unit **16** through a conduit **36** (referenced in FIGS. **1** and **6**). As will be described further below, different cleaning attachment assemblies engageable with the trucks **30**, **32** may be configured to work with fluid at different levels of pressure. For example, one or more cleaning attachment assemblies may operate using fluid at five thousand PSI. Such a cleaning attachment assembly may use the fluid itself to remove foreign matter. Other cleaning attachment assemblies may use fluid at lower pressure in combination with a brush or pad. Fluid can be directed through the conduit **36** with a pump drawing fluid from a reservoir. Such a pump and reservoir (not shown) can be disposed on the top of the building **14**.

[0032] One or more embodiments of the present disclosure can include a sub-system configured to deliver substantially pure water to the cleaning unit **16** to inhibit the formation of spots on the windows. A reverse osmosis and deionization unit with a possible collection tank can be used to supply substantially pure water. Pure water can be water having less than ten parts per million of total dissolved solids. One or more cleaning agencies may require some type of lubricant in the fluid, such as a slight inflow of detergent.

[0033] The conduit **36** can be arranged to direct the fluid to a fluid circuit of the present disclosure with an entry port **38** positioned within the second truck **32**, as shown in FIG. **6**. The fluid circuit can extend from the entry port **38** to a port **40**. The fluid circuit can extend from the port **40** by way of a flexible hose **42** exiting the second truck **32**. The hose **42** can extend from the second truck **32** to a housing **44** of the cleaning attachment assembly **34**. The hose **42** can include a quick-connect fitting to allow the user to easily attach and detach the hose **42** from the truck **32**. The other end of the hose **42** can be permanently attached to the cleaning attachment assembly **34** in one or more embodiments of the present disclosure.

[0034] FIG. **3** illustrates the exemplary housing **44** in operation and FIG. **4** illustrates the housing **44** with a portion removed and/or transparent to reveal internal structures. The hose **42** can extend to a port **46** within the housing **44**. A portion of the fluid circuit within the housing **44** can include a plurality of conduits defining a plurality of fluid passageways in the exemplary embodiment of the present disclosure. For example, the fluid circuit can include a conduit within the housing **44** arranged to deliver fluid to at least one cylinder that is operable to extend in response to the delivery of pressurized fluid. Such a cylinder can be a single-acting cylinder in that the cylinder extends in response to the delivery of pressurized fluid and retracts when the delivery of pressurized fluid ceases. A biasing device urging the cylinder to a fully-retracted configuration can be positioned on the outside of the cylinder or internally. A schematic illustration of the cleaning unit **16** when a cylinder is in a fully-retracted position is illustrated in solid line in FIG. **2**. A schematic illustration of the cleaning unit **16** when a cylinder is in an extended position is illustrated in dashed line (in phantom) in FIG. **2**.

[0035] It is noted that the engagement between the first and second trunks **30**, **32** and the cleaning attachment assembly **34** can be modular in that a plurality of differently-configured cleaning attachment assemblies can be selectively engagable with the first and second trunks **30**, **32**. In other words, a first cleaning attachment assembly can be mounted on the first and second trunks **30**, **32**; operated to remove debris; removed without damage to the first truck **30**, the second truck **32**, and the first cleaning assembly; and

replaced with a second cleaning attachment assembly that can be mounted on the first and second trunks **30**, **32** and operated to remove debris.

[0036] In the exemplary embodiment of the present disclosure, the cleaning attachment assembly **34** can include a plurality of cylinders, such as two cylinders on each lateral side of the housing **44**. For example, the exemplary cleaning attachment assembly **34** can include cylinders **48** and **50** extending from a first lateral side of the housing **44** and cylinders **52** and **54** extending from a second lateral side of the housing **44** opposite the first lateral side. All of the cylinders **48-54** can receive pressurized fluid from the fluid circuit in the exemplary embodiment of the present disclosure to extend concurrently in response to the delivery of pressurized fluid. The exemplary cylinders **48-54** are operable to extend to urge the cleaning agency **28** toward the work surface **24**.

[0037] Each of the exemplary cylinders **48-54** can be received in one or more sleeves fixedly associated with the first and second trucks **30**, **32**. Referring now to FIG. **5**, a sleeve **56** can be mounted on the truck **32**. A similar sleeve can be mounted on the truck **30**. The sleeve **56** can have a C-shaped cross-section or any other shape and extend from an opening **58** to a base **60**. The rod ends of the cylinders **48** and **50** can be received through the opening **58** and be directed through apertures **62**, **64** in the base **60**. Fasteners such as nuts can be utilized to secure the rod ends to the sleeve **56** and thus secure the cylinders **48** and **50** to the truck **32**.

[0038] Each of the exemplary cylinders **48-54** can be pivotally engaged with the housing **44** and the fluid circuit can include valving to allow the cylinders **48-54** to be variably extended. For example, in one or more embodiments of the present disclosure, the cylinders **48** and **50** could be extended differently to allow the housing **44** to tilt or pivot if desired. The cylinders **48** and **50** could thus be controlled to execute a wiping motion at the bottom of a window mimicking the movement executed by human window washer.

[0039] The plurality of cylinders **48-54** can thus define a moving device operably disposed between the cleaning unit **16** and the cleaning agency **28** whereby a distance separating at least part of the cleaning unit **16** and the cleaning agency **28** in a vertically-extending plane transverse to both of the front side **22** and the back side **26** is variable. FIG. **2** is an illustration in a vertically-extending plane transverse to both of the front side **22** and the back side **26**. The distance, for example between the trucks **30**, **32** and the cleaning agency **28** can increase during extension of the cylinders **48-54** and can decrease during retraction of the cylinders **48-54**. In the exemplary embodiment, extension of the cylinders **48-54** can occur along only a horizontal axis in the vertically-extending plane.

[0040] Referring again to FIG. **4**, a portion of the fluid circuit within the housing **44** can also include one or more conduits defining one or more fluid passageways directing fluid to a sprayer manifold **66**. The exemplary sprayer manifold **66** can include a plurality of apertures, such as aperture **68**, arranged along its width for directing fluid at the surface **24** of the window **12**. The apertures **68** can be evenly spaced from one another and similarly sized, or can be differently-sized and unevenly spaced.

[0041] Referring again to FIG. **1**, the positioning unit **18** can include at least one flexible, elongate member. The cleaning unit **16** can be at least partially suspended from building **14** by the at least one flexible, elongate member. In the exemplary embodiment of the present disclosure, each of the trucks **30**, **32** can be suspended from a top of the building with a flexible, elongate member. The at least one flexible, elongate member can be a rope, a cable, a cord, a wire, or any other structure which can be wound and unwound and from which the cleaning unit **16** can be supported. The elongate member can be constructed of a braided aramid fiber, thermoset liquid crystalline polyoxazole fiber or any other sufficiently strong, flexible and corrosion-resistant material, able to withstand tension of up to several hundred pounds, depending upon wall height, and that exhibits extremely low to zero stretch and extremely low to zero creep and is resistant to ultraviolet light rays.

[0042] The first truck **30** can be suspended with a first flexible, elongate member **70** extending in a first loop. The second truck **32** can be suspended with a second flexible, elongate member **72** extending in a second loop. As the cylinders **48-54** extend and urge the cleaning agency **28** against the window **12**, the trucks **30** and **32** can be biased outward, away from the building **14**. Thus, the elongate members **70**, **72** are also urged away from the work surface **24** by extension of the cylinders **48-54**. This "compound bow" effect induced in the elongate members **70**, **72**, best shown in FIG. **2**, can be desirable to keep the cleaning unit **16** against the side of the building **14**. An angular deflection **74** of the cleaning unit **16** during extension of the cylinders **48-54** can vary as desired.

[0043] The positioning unit **18** can also include at least one tensioning unit mounted on the cleaning unit **16**. The at least one tensioning unit can be configured to inhibit slack in the at least one flexible, elongate member. The exemplary embodiment of the present disclosure can include first and second tensioning units disposed on opposite sides of the cleaning unit **16**. A tensioning unit can be mounted on each of the trucks **30**, **32**.

[0044] FIG. **6** shows a tensioning unit **76** mounted on the truck **32**. It is noted that FIGS. **5** and **6** show opposite sides of the truck **32**. The inner cavity of the truck **32** can be divided so that the sleeve **56** is positioned in a first portion of the interior of the truck **32**, as shown in FIG. **5**. In FIGS. **5** and **6**, the outer walls of the truck **32** are cutaway. The first portion can be facing inwardly, toward a center of the cleaning unit **16**. The elongate member **72** can pass through a second portion of the interior of the truck **32**, as shown in FIG. **6**. The sleeve **56** is not shown in FIG. **5** to allow the second portion of the interior of the truck **32** to be shown in greater detail. The second portion can be facing outwardly, away from the center of the cleaning unit **16**. An interior panel referenced at **33** can separate the first and second interior portions of the truck **32**. The interior of the truck **30** can be similar to the interior of the truck **32**.

[0045] Referring now to FIG. **8**, the tensioning unit **76** can include a rod **78**. The elongate member **72** can extend through the rod **78**. The tensioning unit **76** can also include at least one ratchet **80** fixed to the rod **78**. The tensioning unit **76** can also include a pawl **82** mounted on the truck **32** and positioned to engage the ratchet **80**. The tensioning unit **76** can also include a cylinder **84** and a lever arm **86**. The cylinder **84** can be in fluid communication with the conduit **36** through the fluid circuit. In response to fluid pressure, cylinder **84** can be urged to extend. If slack exists in the elongate member **72**, the cylinder **84** can extend. Extension

of the cylinder **84** moves the lever arm **86**, which causes the ratchet **80** and rod **78** to rotate. Rotation of the rod **78** winds the elongate member **72** further about the rod **78**. Winding the elongate member **72** further about the rod **78** takes up and/or inhibits slack in the elongate member **72**. After the slack has been taken-up, the pawl **82** locks the ratchet **80** and prevents reverse rotation of the rod **78**. A tensioning unit similar to tensioning unit **76** can be positioned on the truck **30**. A portion of the fluid circuit within the housing **44** can also include one or more conduits defining one or more fluid passageways directing fluid to the truck **30**.

[0046] The positioning unit **18** can also include an emergency brake unit **88** disposed on the cleaning unit **16**. As best shown in FIG. **7**, the elongate member **72** can be wound over a brake shoe clevis **90** of the emergency brake unit **88**. The brake shoe clevis **90** can be mounted on a pivot shaft **92** for free rotation. The pivot shaft **92** can be moveable relative to the truck **32** and biased toward a brake shoe **94** of the emergency brake unit **88** by a spring **96** of the emergency brake unit **88**. The elongate member **92**, when in tension, can urge the brake shoe clevis **90** away from the brake shoe **94**. If the elongate member **72** is severed, the tension is lost and the brake shoe clevis **90** can be pressed against the brake shoe **94** by the spring **96**, capturing the elongate member **72**.

[0047] The positioning unit **18** can also include an upper positioning assembly **98** mountable proximate to or at the top of the building **14**, above the highest row of windows. Referring now to FIG. **9**, the upper positioning assembly **98** can include a track **100** fixed to the building **14** and a carriage **102** moveable along the track **100**, laterally back and forth across the building **14**. The carriage **102** extends a width between a right carriage side **122** and a left carriage side **124**. The upper positioning assembly **98** can also include a vertical adjustment assembly **104** mounted to the carriage **102**. The vertical adjustment assembly **104** can be operable to rotate the elongate member **72**, which is arranged as a loop. As will be detailed below, the elongate member **70** can be rotated by a vertical adjustment assembly of a lower positioning assembly of the positioning unit **18**. When the loops defined by the elongate members **70**, **72** are rotated in a first rotational direction, the cleaning unit **16** is moved vertically upward. When the loops defined by the elongate members **70**, **72** are rotated in a second rotational direction opposite to the first rotational direction, the cleaning unit **16** is moved vertically downward. The upper positioning assembly **98** can also include a lateral adjustment assembly **106** mounted to the carriage **102**. The lateral adjustment assembly **106** can be operable to drive the carriage **102** in movement along the track **100**. The vertical adjustment assembly **104** and the lateral adjustment assembly **106** are interconnected with respect to one another through the carriage **100**. The vertical adjustment assembly **104**, the lateral adjustment assembly **106**, and the elongate members **70**, **72** can thus move together, back and forth across a side of the building **14**. The components of the upper positioning assembly **98** can be enclosed in an enclosure **118**; portions of the enclosure **118** have been removed in FIG. **9** to reveal internal structures.

[0048] The positioning unit **18** can also include a lower positioning assembly **108** mountable at the bottom of the building **14** or at some point on the building **14** below the top of the building **14**. Referring now to FIG. **10**, the lower positioning assembly **108** can include a track **110** fixed to the building **14** and a carriage **112** moveable along the track **110**, laterally back and forth across the building **14**. The carriage **112** extends a width between a right carriage side **126** and a left carriage side **128**. The lower positioning assembly **108** can also include a vertical adjustment assembly **114** mounted to the carriage **112**. The vertical adjustment assembly **114** can be operable to rotate the elongate member **70**. The lower positioning assembly **108** can also include a lateral adjustment assembly **116** mounted to the carriage **112**. The lateral adjustment assembly **116** can be operable to drive the carriage **112** in movement along the track **110**. The vertical adjustment assembly **114** and the lateral adjustment assembly **116** are interconnected with respect to one another through the carriage **110**. The vertical adjustment assembly **114**, the lateral adjustment assembly **116**, and the elongate members **70**, **72** can thus move together, back and forth across a side of the building **14**. As set forth in greater detail below, the movement of the upper positioning assembly **98** and the lower positioning assembly **108** can be coordinated such that the lateral movement of the upper positioning assembly **98** and the lower positioning assembly **108** is the same. The components of the lower positioning assembly **108** can be enclosed in an enclosure **120**; portions of the enclosure **120** have been removed in FIG. **10** to reveal internal structures.

[0049] Referring now to FIG. **11**, the vertical adjustment assembly **114** can include a motor **130**, a drive shaft **132**, and a drive sheave **134**. The motor **130** can be positioned on the carriage **112**. The drive shaft **132** can extend from the motor **130** and be driven in rotation by the motor **130**. The motor **130** can be operable to selectively rotate the drive shaft **132** in first and second opposite rotational directions. The drive sheave **134** can be mounted on the drive shaft **132** for concurrent rotation with the drive shaft **132**. The elongate member **70** can extend around the drive sheave **134**. When the drive sheave **134** is rotated in a first rotational direction, the cleaning unit **16** is moved vertically upward. When the drive sheave **134** is rotated in a second rotational direction opposite to the first rotational direction, the cleaning unit **16** is moved vertically downward.

[0050] The vertical adjustment assembly **104** associated with the upper positioning assembly **98** can be substantially similar to the vertical adjustment assembly **114**. The vertical adjustment assembly **104** can include a motor **136**, as referenced in FIG. **9**. Although not referenced by number in the drawings, the vertical adjustment assembly **104** can also include a drive shaft and a drive sheave. In the exemplary embodiment, the vertical adjustment assembly **104** is arranged to mirror the arrangement of the vertical adjustment assembly **114**; the drive sheave of the vertical adjustment assembly **104** is positioned to the left of the motor of the vertical adjustment assembly **104**. The motor can be positioned on the carriage **102**. The drive shaft can extend from the motor and be driven in rotation by the motor. The motor can be operable to selectively rotate the drive shaft in first and second opposite rotational directions. The drive sheave can be mounted on the drive shaft for concurrent rotation with the drive shaft. The elongate member **72** can extend around the drive sheave of the vertical adjustment assembly **104**. When the drive sheave is rotated in a first rotational direction, the cleaning unit **16** is moved vertically upward. When the drive sheave is rotated in a second rotational direction opposite to the first rotational direction, the cleaning unit **16** is moved vertically downward. As will be set forth in greater detail below, the motor **130** and the

motor **136** of the vertical adjustment assembly **104** can be jointly controlled to coordinate and harmonize the movement of the elongate members **70**, **72**.

[0051] In the arrangement of the exemplary embodiment, each of the positioning assemblies **98**, **108** defines a moving arrangement for rotating only one of the first loop defined by the elongate member **70** and the second loop defined by the elongate member **72** and a guiding arrangement for guiding rotation of the other of the first loop and the second loop.

[0052] Referring now to FIG. **12**, the lateral adjustment assembly **116** can include a motor **138**, a drive shaft **140**, and a drive sheave **142**. The motor **138** can be positioned on the carriage **112**. The drive shaft **140** can extend from the motor **138** and be driven in rotation by the motor **138**. The motor **138** can be operable to selectively rotate the drive shaft **140** in first and second opposite rotational directions. A worm gear **144** can be mounted on or defined by the drive shaft **140**. A spur gear **146** can be mounted on or defined by the drive sheave **142**. The spur gear **146** and the worm gear **144** can be meshed such that the drive sheave **142** and the drive shaft **140** are arranged for concurrent rotation.

[0053] The exemplary lateral adjustment assembly **116** can also include an idler sheave **148** and belts **150**, **152** extending around the sheaves **142** and **148**. It is noted that in FIG. **12** portions of the sheaves **142** and **148** have been cut away to reveal other structures. The belts **150**, **152** can be positioned between the sheaves **142**, **148** and the track **110**. When the drive sheave **142** is rotated in a first rotational direction by the drive shaft **142**, the belts **150**, **152** (like vehicle tracks) rotate and the carriage **112** is moved rectilinearly in a first lateral direction. When the drive sheave **142** is rotated in a second rotational direction opposite to the first rotational direction by the drive shaft **142**, the belts **150**, **152** rotate and the carriage **112** is moved rectilinearly in a second lateral direction opposite to the first lateral direction.

[0054] The lateral adjustment assembly **106** associated with the upper positioning assembly **98** can be substantially similar to the lateral adjustment assembly **116**. Each of the lateral positioning assemblies **106**, **116** defines a shifting arrangement for shifting the respective carriage **102**, **112** laterally across the building **14**. The lateral adjustment assembly **106** can include a motor **154**, as referenced in FIG. **9**. Although not referenced by number in the drawings, the vertical adjustment assembly **104** can also include a drive shaft and a drive sheave. The motor **154** can be positioned on the carriage **102**. The drive shaft can extend from the motor **154** and be driven in rotation by the motor **154**. The motor **154** can be operable to selectively rotate the drive shaft in first and second opposite rotational directions. A worm gear can be mounted on or defined by the drive shaft. A spur gear can be mounted on or defined by the drive sheave. The spur gear and the worm gear can be meshed such that the drive sheave and the drive shaft are arranged for concurrent rotation.

[0055] The exemplary lateral adjustment assembly **106** can also include an idler sheave and belts extending around the drive and idler sheaves of the assembly **106**. The belts of the assembly **106** can be positioned between the drive and idler sheaves of the assembly **116** and the track **100**. When the drive sheave is rotated in a first rotational direction by the drive shaft of the assembly **106**, the belts (like vehicle tracks) rotate and the carriage **102** is moved rectilinearly in a first lateral direction. When the drive sheave of the assembly **106** is rotated in a second rotational direction opposite to the first rotational direction by the drive shaft of the assembly **106**, the belts of the assembly **106** rotate and the carriage **102** is moved rectilinearly in a second lateral direction opposite to the first lateral direction. As will be set forth in greater detail below, the motor **138** and the motor **154** of the lateral adjustment assembly **106** can be jointly controlled to coordinate and harmonize the movement of the carriages **102** and **112**.

[0056] Referring again to FIG. **11**, the vertical adjustment assembly **114** can also include idler sheaves **156** and **158**. It is noted that in FIG. **11** portions of the sheaves **156** and **158** have been cut away to reveal other structures. The vertical adjustment assembly **114** can also include belts **160** and **162**. The belts **160**, **162** can extend around the sheaves **156** and **158**. The belts **160**, **162** can be positioned between the sheaves **156**, **158** and the track **110**. Lateral movement of the carriage **112** can be effectuated by the lateral adjustment assembly **116** and the sheaves **156**, **158** and belts **160**, **162** of the vertical adjustment assembly **114** can guide the movement of the carriage **112**. The vertical adjustment assembly **104** can also include idler sheaves and belts similar to the sheaves **156**, **158** and belts **160**, **162**.

[0057] Referring again to FIG. **12**, the lateral adjustment assembly **116** can also include an idler sheave **164**. The idler sheave **164** can be mounted for free rotation on a shaft that abuts the shaft **140**. There can be double bearings between the idler sheave **164** and the shaft **140** with a divider between. Distinct, adjacent shafts can be desirable to inhibit the encoder **172**, during lateral movement, from giving false readings. The shaft **140** can therefore rotate without inducing rotation in the idler sheave **164**. The elongate member **72** can extend around the idler sheave **164**. Rotation of the loop defined by the elongate member **72** can induce rotation of the idler sheave **164**. The lateral adjustment assembly **116** can also include an idler sheave similar to the idler sheave **164**.

[0058] It is noted that in some embodiments of the present disclosure, an adjustment assembly can include structures to function as both a lateral adjustment assembly and a vertical adjustment assembly. For example, the shaft **140** referenced in FIG. **12** could drive the sheave **164** as well as the sheave **142** if desired.

[0059] It is also noted that each adjustment assembly can include an emergency brake unit similar to the emergency brake unit **88**. An emergency brake unit disposed on an adjustment assembly **104**, **106**, **114**, and/or **116** can include a brake shoe clevis and a brake shoe. The respective elongate member **70** or **72** can be wound over the brake shoe clevis of the emergency brake unit associated with the respective adjustment assembly **104**, **106**, **114**, or **116**. The brake shoe clevis can be mounted on a pivot shaft for free rotation. The pivot shaft can be moveable relative to the respective adjustment assembly **104**, **106**, **114**, or **116** and biased toward the brake shoe by a spring of the emergency brake unit. The respective elongate member **70** or **72**, when in tension, can urge the brake shoe clevis away from the brake shoe. If the respective elongate member **70** or **72** is severed, the tension is lost and the brake shoe clevis can be pressed against the brake shoe by the spring, capturing the respective elongate member **70** or **72**. An emergency brake unit is referenced in FIG. **11** at **202**. An emergency brake unit is referenced in FIG. **12** at **204**.

[0060] Referring again to FIGS. **9** and **10**, the positioning unit **18** can also include a master processor **166** and a slave

processor **168**. While one processor is illustrated for each of the master processor **166** and the slave processor **168**, it should be appreciated that the term "processor" can include two or more processors that operate in an individual or distributed manner. In the exemplary embodiment, the master processor **166** can be disposed on the upper positioning assembly **98** and the slave processor **168** can be disposed on the lower positioning assembly **108**. The master processor **166** can control the motors **136** and **154**. The slave processor **168** can control the motors **130** and **138**. The exemplary master processor **166** and/or the exemplary slave processor **168** can be a STM32F205 120 Mhz ARM Cortex M3 processor from ST Microelectronics with a Broadcom BCM43362 Wi-Fi chip or a Hope RFM69HW transceiver. There are any number of processors and RF radios that could be utilized in one or more embodiments of the present disclosure. Many of them can be purchased as a single unit. The processors **166**, **168** can be an RF device with high RF output power and channelized operation that is compliant with ETSI and FCC regulations over a wide frequency range, including the 315, 433, 868 and 915 MHz license-free ISM frequency bands.

[0061] Referring again to FIG. **11**, the vertical adjustment assembly **114** can include a sensor disposed to sense movement of the idler sheave **158** and emit a signal in response to the sensed movement. Movement of the idler sheave **158** corresponds to lateral movement of the lower positioning assembly **108**. The sensor can be a quadrature encoder **170**. The encoder **170** can track the motion of the idler sheave **158**. The encoder **170** may be any quadrature encoder that is capable of delivering a pulse resolution matching the step resolution of the lateral drive motor **154** of the upper positioning assembly **98**. The vertical adjustment assembly **104** of the upper positioning assembly **98** can also include a sensor similar to the encoder **170**.

[0062] Referring again to FIG. **12**, lateral adjustment assembly **116** can include a sensor disposed to sense movement of the idler sheave **164** and emit a signal in response to the sensed movement. Movement of the idler sheave **164** corresponds to rotational movement of the loop defined by the elongate member **72**. The sensor can be a quadrature encoder **172**. The encoder **172** can track the motion of the idler sheave **164**. The encoder **172** may be any quadrature encoder that is capable of delivering a pulse resolution matching the step resolution of the vertical drive motor **136** of the upper positioning assembly **98**. The lateral adjustment assembly **106** of the upper positioning assembly **98** can also include a sensor similar to the encoder **172**.

[0063] In operation, when the cleaning unit **16** is to be moved vertically, the master processor **166** can calculate the amount of rotation required of the drive shaft of the motor **136** and also determine the direction of rotation required to accomplish the desired movement. The master processor **166** can then send a command to the slave processor **168** to begin vertical movement. The slave processor **168** can respond with a "ready" response or a "busy" response. When the slave processor **168** transmits the ready response to the master processor **166**, the master processor **166** controls the motor **136** to commence rotation of the drive shaft extending from the motor **136**. This induces rotation of the loop defined by the elongate member **72**.

[0064] The idler sheave **164** of the lateral adjustment assembly **116** commences rotation, driven by the elongate member **72**. The encoder **172** senses movement of the sheave **164** and transmits a signal corresponding to the movement to the slave processor **168** in the form of electronic pulses. The slave processor **168** reads each pulse and in response transmits a corresponding pulse to control the motor **130** to rotate the shaft **132**. The drive shaft **132** rotates the drive sheave **134**. Rotation of the drive shaft **132** therefore induces rotation of the loop defined by the elongate member **70**. Thus rotation of the loop defined by the elongate member **70** is responsive to rotation of the loop defined by the elongate member **72** and in lock step with rotation of the loop defined by the elongate member **72**.

[0065] A rotary encoder associated with an idler sheave of the lateral adjustment assembly **106** is disposed to sense rotation of that idler sheave. This encoder is referenced at **194** in FIG. **13**. As the loop defined by the elongate member **70** rotates, the rotary encoder **194** associated with an idler sheave of the lateral adjustment assembly **106** senses the rotation and transmits a signal corresponding to the rotation to the master processor **166**. The master processor **166** can then determine the rate of rotation of loop defined by the elongate member **70**. A closed loop feedback system is thus defined to insure the rotation of both loops is synchronized so that both sides of the cleaning unit **16** are moved similarly. The processors **166**, **168** can be configured to take corrective action, such as slightly moving only one of the drive sheaves of the vertical adjustment assemblies **104**, **114** to bring the elongate members **70**, **72** back into synchronization. Also, at least one of the processors **166**, **168** can be configured to emit a warning message to a user if the elongate members **70**, **72** are determined to be out of synchronization. Such a warning message can be done in conjunction with corrective action, prior to corrective action, or if one or both of the processors **166**, **168** determine that corrective action has not been successful.

[0066] In operation, when the cleaning unit **16** is to be moved laterally, the master processor **166** can calculate the amount of rotation required of the drive shaft of the motor **154** and also determine the direction of rotation required to accomplish the desired movement. The master processor **166** can then send a command to the slave processor **168** to begin lateral movement. The slave processor **168** can respond with a "ready" response or a "busy" response. When the slave processor **168** transmits the ready response to the master processor **166**, the master processor **166** can control the motor **154** to commence rotation of the drive shaft extending from the motor **154**. This induces rotation of the sheaves associated with the motor **154** and belts encircling those sheaves. Concurrently, the slave processor **168** can control the motor **138** to commence rotation of the drive shaft **140**, which induces rotation of the sheave **142** and belts **150**, **152**.

[0067] During lateral movement, the slave processor **168** can monitor signals from the encoder **170**, the signals indicative of the movement of the carriage **112**. Similarly, the master processor **166** can monitor signals from an encoder associated with the vertical adjustment assembly **104**, the signals indicative of the movement of the carriage **102**. This encoder is referenced at **196** in FIG. **13**.

[0068] The master and slave processors **166**, **168** can monitor the motion of the respective carriages **102**, **112** to ensure synchronized motion. The slave processor **168** can transmit the signals from the encoder **170** to the master processor **166**. The master processor **166** can compare the signals from the encoder **170** to the signals of the encoder

196, which is associated with the vertical adjustment assembly 104. If the carriages 102, 112 are determined to be out of synchronization, the master processor 166 can control the motor 154 and the slave processor 168 to cease. The processors 166, 168 can also be configured to take corrective action, such as slightly moving only one of the carriages 102, 112 to bring the carriages 102, 112 back into synchronization. Also, at least one of the processors 166, 168 can be configured to emit a warning message to a user if the carriages 102, 112 are determined to be out of synchronization. Such a warning message can be done in conjunction with corrective action, prior to corrective action, or if one or both of the processors 166, 168 determine that corrective action has not been successful.

[0069] Referring now to FIG. 13, a control system according to an exemplary embodiment of the present disclosure. The control system can include the master processor 166 and the slave processor 168. The control system can also include limit switches 174. A limit switch 174 can be associated with each elongate member 70, 72. Each limit switch 174 can communicate signals to the master processor 166. Each limit switch 174 can be tripped if one of the loops defined by the elongate members 70, 72 is rotated beyond a desired range. In response to one of the limit switches 174 being tripped, the master processor 166 can control the motor 136 and the slave processor 168 to cease. The slave processor 168 can also communicate with limit switches 175. There can also be lateral limit switches located on either side of the upper carriage 102 and of the lower carriage 112 that can be tripped if either carriage reaches the end of the track 100, 110 on either side. Such switches can communicate with the respective processors 166, 168.

[0070] In one or more exemplary embodiments of the present disclosure, the control system can also include a managing processor 176. The managing processor can also be a STM32F205 120 Mhz ARM Cortex M3 processor from ST Microelectronics with a Broadcom BCM43362 Wi-Fi chip or a Hope RFM69HW transceiver. In one or more embodiments, the managing processor 176 can be remote from the building 14. The managing processor 176 can be cloud-based. The managing processor 176 can direct movement commands to the master processor 166. In one or more embodiments of the present disclosure, the processors 176, 166, and 168 can communicate with one another over a mesh network. The control system can also include one or more power sources, such as power source 178. In one example, the power source 178 can be a source of electrical power and the managing processor 176 can control the flow of electrical power to any device requiring electrical power. Source of power other than electrical power can be a part of the control system of one or more embodiments of the present disclosure and the distribution of such power can be controlled by a managing processor.

[0071] In one or more exemplary embodiments of the present disclosure, the control system can also include a memory 180. Memory 180 can be any suitable storage medium (flash, hard disk, etc.). System programming can be stored in and accessed from memory 180. Building data can also be stored in memory 180. For example, the managing processor 176 can retrieve dimensional data associated with the building 14 from memory 180 and transmit the dimensional data to the master processor 166 when sending a movement request to the master processor 166. Equipment usage data can also be stored in memory 180. The managing processor 176 can alert a user when any particular component requires scheduled maintenance or replacement based on usage data stored in memory 180. A cleaning schedule can also be stored in memory 180. The managing processor 176 can automatically initiate window cleaning based on the cleaning schedule can also be stored in memory 180. It is noted that in one or more embodiments of the present disclosure, the master processor 166 can store and control the cleaning schedule, allowing each apparatus 10 to act independently of every other apparatus on the building 14. It is noted that one or more processors can be mounted on any of the cleaning attachment assemblies. An exemplary processor 220 is illustrated as being mounted on the cleaning attachment assembly 34 in FIG. 4. Such processors can be responsive to any one or all of the processors 166, 168, and/or 170. Such processors can be configured to control solenoid valves for directing fluid flow, or some other purpose.

[0072] Any combination of one or more computer-usable or computer-readable media may be utilized in various embodiments of the invention. For example, a computer-readable medium may include one or more of a portable computer diskette, a hard disk, a random access memory (RAM) device, a read-only memory (ROM) device, an erasable programmable read-only memory (EPROM or Flash memory) device, a portable compact disc read-only memory (CDROM), an optical storage device, and a magnetic storage device. Computer program code for carrying out operations of this invention may be written in any combination of one or more programming languages.

[0073] In one or more exemplary embodiments of the present disclosure, the control system can also include one or more valves 182. A valve can be disposed at each of the cylinders 48-54. A valve can be disposed along the conduit 36. One or more valves can be positioned within the fluid circuit to selectively permit flow to a cleaning agency or portions of a cleaning agency. The managing processor 176 can control valves 182 within the system as desired.

[0074] In one or more exemplary embodiments of the present disclosure, the control system can also include one or more pumps 184. A pump can be disposed at intake of the conduit 36 and be operable to deliver pressurized fluid to the cleaning unit 16. A pump can be disposed on the cleaning unit 16. The managing processor 176 can control pumps 184 within the system as desired.

[0075] In one or more exemplary embodiments of the present disclosure, the control system can also include one or more motors 186 in addition to the motors already disclosed. A motor can be disposed on one or more of the cleaning attachment assemblies. The managing processor 176 can control motors 186 within the system as desired.

[0076] In one or more exemplary embodiments of the present disclosure, the power source 178 can be based on solar power and the control system can also include a charger 188. The charger 188 can include one or more solar panels. The solar panels can be mounted on the upper and/or lower positioning assemblies, and/or on the cleaning unit 16. Alternatively, if solar panels were used to power the system, such panels would most likely be positioned on the roof of the building 14 and feed a bank of batteries. The power source 178 can include one or more batteries. The solar panels can transmit electrical power for storage in the one or more batteries. The charger 188 can apply a charging algorithm in controlling the flow of electrical power from

the solar panels (or from an electrical grid) to the one or more batteries. The managing processor **176** can control the charger **188** as desired.

[0077] In one or more exemplary embodiments of the present disclosure, the control system can also include a camera **190** and a camera mover **192**. This camera **192** can be a self-contained unit about 0.76 inch in diameter by about 3.15 inches long that contains its own battery and 2.4 GHz wireless transmitter. The battery could be rated at 280 mAH with a working time of 1.2 hours. The camera **190** could also draw power from batteries external to the camera, such as batteries mounted inside the cleaning unit or truck. The camera **190** could be mounted on the trucks to inhibit overspray on the lens, as shown in FIG. **3**. The lens of the camera **190** could be hydrophilic-coated glass to inhibit overspray of fluid and facilitate a clear image and higher resolution. The camera **190** can transmit image data to the managing processor **176**. The camera mover **192** can change the orientation of the camera **190** to change the field of view of the camera **190**. The camera mover **192** can be integral with the camera **190**.

[0078] The image data can be processed to assess the effectiveness of the cleaning process. The image data can also be processed to detect structural problems of the building **14** and inspect the building. For example, the image data can be stored and analyzed visually by a qualified technician or engineer, or processed by a computer program to analyze and identify defects or anomalies in the building structure or façade. Some items that can be searched for and/or visually inspected during the examination of a building include weather-tightness of the facade; cracks; displacement (outward shifting of facade unit); mold; mildew; rust; rot; cracks in masonry; water stains; spalls (sections where materials come apart); and the condition of flashing, sealant, weather stripping, and caulking. One or more embodiments of the present disclosure can include software configured to identify such items in image files. If a problem is detected, at least one of the processors **166**, **168**, **176** can be configured to emit a warning message to a user.

[0079] It is noted that one or more embodiments of the present disclosure could omit the cleaning attachment assembly **34** and utilize the trucks **30**, **32** and some structure interconnecting the trucks **30**, **32** to support a camera. Such a system could be operated as a device for inspecting the building **14**. Further, one or more embodiments of the present disclosure could utilize a single one of the trucks **30**, **32** to support a camera for building inspection.

[0080] In one or more exemplary embodiments of the present disclosure, the control system can also include one or more meteorological sensors **198**. A meteorological sensor can be operable to detect the direction and velocity of wind. A meteorological sensor can be operable to detect rain/moisture. A meteorological sensor can be operable to detect temperature. The managing processor **176** can receive signals from the meteorological sensors **198** and control devices of the control system in response to signals from the meteorological sensors **198**.

[0081] In one or more exemplary embodiments of the present disclosure, the control system can also include one or more fluid sensors **200**. A fluid sensor can be operable to detect a rate of fluid flow and/or a pressure of fluid. A fluid sensor can be positioned in the conduit **36** and/or along the fluid circuit. The managing processor **176** can receive signals from the fluid sensors **200** and control devices of the control system in response to signals from the fluid sensors **200**.

[0082] Referring now to FIG. **14**, a first alternative cleaning attachment assembly **34***a* according to an exemplary embodiment of the present disclosure can include a non-rotating brush **28***a* as a cleaning agency. The cleaning attachment assembly **34***a* can include a housing **44***a*. A hose **42***a* can extend from a first truck (not shown) to the interior of the housing **44***a*. A hose **43***a* can extend from the housing **44***a* to a second truck (not shown). The cleaning attachment assembly **34***a* can include a plurality of cylinders **48***a*-**54***a*. The cylinders **48***a*-**54***a* can be pivotally engaged with the housing **44***a*. The cleaning agency **28***a* in the form of a non-rotating brush can be mounted on the housing **44***a*. The cleaning attachment assembly **34***a* can also include sprayer manifolds **66***a* and **66***aa*.

[0083] In operation, pressurized fluid (about eighty to one hundred and twenty-five PSI) can be directed to the cleaning attachment assembly **34***a* and be distributed through the fluid circuit within the housing **44***a*. The fluid can be equally distributed among the cylinders **48***a*-**54***a* and the sprayer manifolds **66***a* and **66***aa*. One or more solenoid valves can be positioned on the cleaning unit and opened to release the pressurized fluid to the cylinders **48***a*-**54***a*. Each cylinder or pairs of cylinders can have a dedicated solenoid valve so that the cylinders can be selectively extended and retracted. The cylinders **48***a*-**54***a* can extend and press the brush **28***a* against the window surface. The one or more solenoid valves can be controlled by one of the processors **166**, **168**, **176**. The positioning unit can move the cleaning unit supporting the cleaning attachment assembly **34***a* vertically the height of the window surface. At the bottom of the window, the solenoid valve can be closed, resulting in retraction of the cylinders **48***a*-**54***a*. The processors of the positioning unit can agitate the brush **28***a* back and forth by moving the upper and lower carriages **102**, **112** laterally to clean the top and bottom of the window frame, or can agitate the brush **28***a* back and forth in a zigzag motion as the brush **28***a* is descending along the window surface. This attachment **34***a* can be particularly useful in cleaning walls, trim and windows.

[0084] Referring now to FIG. **15**, a second alternative cleaning attachment assembly **34***b* according to an exemplary embodiment of the present disclosure can include a microfiber pad assembly **28***b* as a cleaning agency. The microfiber pad assembly **28***b* can include microfiber pad pressed against the window and a microfiber pad support being an ultra-highly absorbent material such as sponge or super-absorbent polymer. The cleaning attachment assembly **34***b* can include a housing **44***b*. A hose **42***b* can extend from a first truck (not shown) to the interior of the housing **44***b*. A hose **43***b* can extend from the housing **44***b* to a second truck (not shown). The cleaning attachment assembly **34***b* can include a plurality of cylinders **48***b*-**54***b*. The cylinders **48***b*-**54***b* can be pivotally engaged with the housing **44***b*. The cleaning agency **28***b* in the form of a microfiber pad assembly can be mounted on the housing **44***b*. The cleaning attachment assembly **34***b* can also include sprayer manifolds **66***b* and **66***bb*.

[0085] In operation, pressurized fluid (about eighty to one hundred and twenty-five PSI) can be directed to the cleaning attachment assembly **34***b* and be distributed through the fluid circuit within the housing **44***b*. The fluid can be equally

distributed among the cylinders **48***b*-**54***b* and the sprayer manifolds **66***b* and **66***bb*. One or more solenoid valves can be positioned on the cleaning unit and opened to release the pressurized fluid to the cylinders **48***b*-**54***b*. Each cylinder or pairs of cylinders can have a dedicated solenoid valve so that the cylinders can be selectively extended and retracted. The cylinders **48***b*-**54***b* can extend and press the microfiber pad assembly **28***b* against the window surface. The one or more solenoid valves can be controlled by one of the processors **166**, **168**, **176**. The positioning unit can move the cleaning unit supporting the cleaning attachment assembly **34***b* vertically the height of the window surface. At the bottom of the window, the solenoid valve can be closed, resulting in retraction of the cylinders **48***b*-**54***b*. The processors of the positioning unit can agitate the microfiber pad assembly **28***b* back and forth by moving the upper and lower carriages **102**, **112** laterally to clean the top and bottom of the window frame, or can agitate the microfiber pad assembly **28***b* back and forth in a zigzag motion as the microfiber pad assembly **28***b* is descending along the window surface. This attachment **34***b* can be particularly useful in cleaning the glass surface of the window.

[0086] Referring now to FIG. **16**, a third alternative cleaning attachment assembly **34***c* according to an exemplary embodiment of the present disclosure can include a rotating brush **28***c* as a cleaning agency. An alternate embodiment might also include a rotating drum covered in microfiber instead of the brush. The cleaning attachment assembly **34***c* can include a housing **44***c*. A hose **42***c* can extend from a first truck (not shown) to the interior of the housing **44***c*. A hose **43***c* can extend from the housing **44***c* to a second truck (not shown). The cleaning attachment assembly **34***c* can include a plurality of cylinders, such as cylinders **48***c* and **52***c*. The cylinders **48***c*, **52***c* can be pivotally engaged with the housing **44***c*. The cleaning agency **28***c* in the form of a rotating brush can be mounted on the housing **44***c*. The cleaning attachment assembly **34***c* can also include a sprayer manifold **66***c*.

[0087] The cleaning attachment assembly **34***c* can also include hydraulic motors **206***c* and **208***c*. An alternate embodiment might include electric motors driven by batteries. The motors could be switched by a hydraulic-actuated relay that closes when pressure is applied through the hose. The motors **206***c* and **208***c* can rotate the brush **28***c*. One or more solenoid valves can be positioned on the cleaning unit and opened to release the pressurized fluid to the motors **206***c* and **208***c* to rotate the brush **28***c*. The one or more solenoid valves can be controlled by one of the processors **166**, **168**, **176**. Alternatively, the motors **206***c*, **208***c*, can be powered by the fluid pressure without solenoid valves such that when pressure is released, rotation stops.

[0088] In operation, pressurized fluid (about eighty to one hundred and twenty-five PSI) can be directed to the cleaning attachment assembly **34***c* and be distributed through the fluid circuit within the housing **44***c*. The fluid can be equally distributed among the cylinders **48***c*, **52***c*, any other cylinder, and the sprayer manifold **66***c*. One or more solenoid valves can be positioned on the cleaning unit and opened to release the pressurized fluid to the cylinders **48***c*, **52***c*, and any other cylinder. Each cylinder or pairs of cylinders can have a dedicated solenoid valve so that the cylinders can be selectively extended and retracted. The cylinders **48***c*, **52***c*, and any other cylinder can extend and press the rotating brush **28***c* against the window surface. The one or more solenoid valves can be controlled by one of the processors **166**, **168**, **176**. The positioning unit can move the cleaning unit supporting the cleaning attachment assembly **34***c* vertically the height of the window surface. At the bottom of the window, the solenoid valve can be closed, resulting in retraction of the cylinders **48***c*, **52***c*, and any other cylinder. The processors of the positioning unit can agitate the rotating brush **28***c* back and forth by moving the upper and lower carriages **102**, **112** laterally to clean the top and bottom of the window frame, or can agitate the rotating brush **28***c* back and forth in a zigzag motion as the rotating brush **28***c* is descending along the window surface. This attachment **34***c* can be particularly useful in cleaning walls, trim and windows.

[0089] Referring now to FIG. **17**, a fourth alternative cleaning attachment assembly **34***d* according to an exemplary embodiment of the present disclosure can include a plurality of cleaning agencies, such as a blade **28***d* and a brush **28***dd*. The cleaning attachment assembly **34***d* can include a housing **44***d*. A hose **42***d* can extend from a first truck (not shown) to the interior of the housing **44***d*. A hose **43***d* can extend from the housing **44***d* to a second truck (not shown). The cleaning attachment assembly **34***d* can include a plurality of cylinders, such as cylinders **48***d* and **52***d*. The cylinders **48***d*, **52***d* can be pivotally engaged with the housing **44***d*. The first cleaning agency **28***d* in the form of a blade and the second cleaning agency **28***dd* in the form of brush can be mounted on the housing **44***d*. The cleaning attachment assembly **34***d* can also include a sprayer manifold **66***d*.

[0090] The housing **44***d* can include side sections **210***d*, **212***d* and a center section **214***d*. The center section **214***d* can be supported for rotation on the side sections **210***d*, **212***d*. The range of rotation of the center section **214***d* relative to the side sections **210***d*, **212***d* can be less than three hundred and sixty degrees. The blade **28***d* and the brush **28***dd* can be mounted on the center section **214***d* of the housing **44***d*.

[0091] The cleaning attachment assembly **34***c* can also include rotary actuators **216***d* and **218***d*. The rotary actuators **216***d* and **218***d* can rotate the center section **214***d*. One or more solenoid valves can be positioned on the cleaning unit and opened to release the pressurized fluid to the rotary actuators **216***d* and **218***d* to rotate the center section **214***d*. The one or more solenoid valves can be controlled by one of the processors **166**, **168**, **176**.

[0092] In operation, pressurized fluid (about eighty to one hundred and twenty-five PSI) can be directed to the cleaning attachment assembly **34***d* and be distributed through the fluid circuit within the housing **44***d*. The fluid can be equally distributed among the cylinders **48***d*, **52***d*, any other cylinder, the rotary actuators **216***d* and **218***d*, and the sprayer manifold **66***d*. One or more solenoid valves can be positioned on the cleaning unit and opened to release the pressurized fluid to the cylinders **48***d*, **52***d*, and any other cylinder. Each cylinder or pairs of cylinders can have a dedicated solenoid valve so that the cylinders can be selectively extended and retracted. The one or more solenoid valves can be controlled by one of the processors **166**, **168**, **176**, or by a processor disposed in the cleaning attachment assembly **34***c* itself.

[0093] When the cleaning unit reaches the top of the window surface, the rotary actuators **216***d* and **218***d* can be controlled to position the brush **28***dd* toward the window surface. The cylinders **48***d*, **52***d*, and any other cylinder can then be extended to press the brush **28***dd* against the window surface. The positioning unit can then move the cleaning unit supporting the cleaning attachment assembly **34***c* vertically downward the height of the window surface.

[0094] Once the cleaning unit has completed a vertical pass of the window surface with the brush **28***dd* engaged, the solenoid valves associated with the cylinders **48***d*, **52***d*, and any other cylinder can be closed, resulting in retraction of the cylinders **48***c*, **52***c*, and any other cylinder. The positioning unit can then return the cleaning unit back to the top of the window. The rotary actuators **216***d* and **218***d* can be controlled to rotate or pivot one hundred and eighty degrees to orient the blade **28***d* toward the window surface. The cylinders **48***d*, **52***d*, and any other cylinder can then be extended to press the blade **28***d* against the window surface. The positioning unit can then move the cleaning unit supporting the cleaning attachment assembly **34***c* vertically downward the height of the window surface to wipe the window surface with the blade **28***d*.

[0095] Referring now to FIG. **18**, a fifth alternative cleaning attachment assembly **34***e* according to an exemplary embodiment of the present disclosure can include a fluid sprayer **28***e* as a cleaning agency. A hose **42***e* can extend from a first truck (not shown) to fluid sprayer **28***e*. A hose **43***e* can extend from the fluid sprayer **28***e* to a second truck (not shown). The cleaning attachment assembly **34***e* can include a plurality of cylinders **48***e*-**54***e*. The cylinders **48***e*-**54***e* can be pivotally engaged with the fluid sprayer **28***e*.

[0096] In operation, pressurized fluid (about three thousand to five thousand PSI) can be directed to the cleaning attachment assembly **34***e* and be distributed through the fluid circuit within the housing **44***e*. It is noted that all of the components of the cleaning attachment assembly **34***e* can be enhanced to be more robust in view of the elevated pressure levels. The pump **184**, the hose **36**, and any solenoid valves in the upper carriage can be more robust as well. The fluid can be equally distributed among the cylinders **48***e*-**54***e* and the fluid sprayer **28***e*. The fluid can pass through a high-pressure regulator capable of reducing pressure from about three thousand to five thousand PSI to about eighty to one hundred and twenty-five PSI before it is distributed to the cylinders and back into the truck through the hose **43***e*. The fluid sprayer **28***e* can be similar to the sprayer manifolds disclosed above, but can be enhanced to be more robust in view of the elevated pressure levels. One or more solenoid valves can be positioned on the cleaning unit and opened to release the pressurized fluid to the cylinders **48***e*-**54***e*. Each cylinder or pairs of cylinders can have a dedicated solenoid valve so that the cylinders can be selectively extended and retracted. The cylinders **48***e*-**54***e* can extend and position the fluid sprayer **28***e* proximate to the window surface. The one or more solenoid valves can be controlled by one of the processors **166**, **168**, **176**. The positioning unit can move the cleaning unit supporting the cleaning attachment assembly **34***e* vertically the height of the window surface. At the bottom of the window, the solenoid valve can be closed, resulting in retraction of the cylinders **48***e*-**54***e*. The processors of the positioning unit can agitate the fluid sprayer **28***e* back and forth by moving the upper and lower carriages **102**, **112** laterally to clean the top and bottom of the window frame, or can agitate the fluid sprayer **28***e* back and forth in a zigzag motion as the fluid sprayer **28***e* is descending along the window surface. This attachment **34***e* can be useful in cleaning any surface.

[0097] It is also noted that in one or more embodiments of the present disclosure, a plurality of trucks **32**, **32** can be mounted on the same flexible elongate members **70**, **72**, each pair supporting a cleaning attachment assembly. The process of cleaning all of the windows of a building can be accelerated by having multiple cleaning units **16** (each with the same cleaning attachment or different cleaning attachments) in use on the same set of elongate members **70**, **72** at the same time. The present disclosure can be capable of allowing for multiple cleaning units in part due the relatively low weight of the cleaning unit. Each cleaning unit can be mounted at a fixed position relative to the elongate members by having tensioning units on each truck, allowing a cleaning unit to rest on clamps fixed to the elongate members, or by clamping the trucks and elongate members together.

[0098] In one or more embodiments of the present disclosure, the cleaning agency could be mounted on one or more pivoting arms. Such arms could be pivotally mounted on the trucks. For example, the cleaning agency could be mounted at first ends of such arms and cylinders could be engaged with opposite, second ends of such arms. The arms could be connected to the trucks by pivot pins. Extension of the arms could result in the cleaning agency being move toward the window. Retraction of the arms could result in the cleaning agency being drawn away from the window.

[0099] While the present disclosure has been described with reference to an exemplary embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the present disclosure. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the present disclosure without departing from the essential scope thereof. Therefore, it is intended that the present disclosure not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this present disclosure, but that the present disclosure will include all embodiments falling within the scope of the appended claims. It is noted that in the apparatus claims, terms preceded "the" are not elements of the claims; claim elements recited after the initial recitation are preceded by "said." The right to claim elements and/or sub-combinations that are disclosed herein as other present disclosures in other patent documents is hereby unconditionally reserved.

What is claimed is:

1. An apparatus adapted for the removal of foreign matter from the exterior of windows of a building and comprising:

a cleaning unit extending a depth between a front side confronting the work surface and a back side opposite said front side, said cleaning unit including a cleaning agency; and

a positioning unit engaged with said cleaning unit to move said cleaning unit among a plurality of different positions relative to the building.

2. The apparatus of claim **1** wherein said positioning unit further comprises:

a first drive sheave configured for mounting proximate to a top of the building;

a first motor disposed to selectively drive said first drive sheave in rotation;

a first idler sheave configured for mounting proximate to a bottom of the building below said first drive sheave;

a second drive sheave configured for mounting proximate to the bottom of the building laterally spaced from said first idler sheave;

a second motor disposed to selectively drive said second drive sheave in rotation;

a second idler sheave configured for mounting proximate to the top of the building above said second drive sheave and laterally spaced from said first drive sheave;

a first flexible, elongate member extending between said first drive sheave and said first idler sheave, said cleaning unit at least partially suspended from said first flexible, elongate member; and

a second flexible, elongate member extending between said second drive sheave and said second idler sheave, said cleaning unit at least partially suspended from said second flexible, elongate member.

3. The apparatus of claim **2** wherein said positioning unit further comprises:

a first sensor disposed to sense movement of said first idler sheave and emit a first signal in response to the sensed movement; and

a processor disposed to receive said first signal and control said second motor in response to said first signal.

4. The apparatus of claim **3** wherein said positioning unit further comprises:

a second sensor disposed to sense movement of said second idler sheave and emit a second signal in response to the sensed movement, wherein said processor is further defined as disposed to receive said second signal and control said first motor in response to said second signal.

5. The apparatus of claim **1** wherein said positioning unit further comprises:

a first carriage configured for mounting proximate to a top of the building and extending a first width between a first right carriage side and a first left carriage side;

a second carriage configured for mounting proximate to a bottom of the building and extending a second width between a second right carriage side and a second left carriage side;

a first flexible, elongate member extending in a first loop between said first carriage and said second carriage at said first right carriage side and said second right carriage side, said cleaning unit at least partially suspended from said first flexible, elongate member, and a first lateral side of said cleaning unit moved vertically by rotation of said first loop;

a second flexible, elongate member extending in a second loop between said first carriage and said second carriage at said first left carriage side and said second left carriage side, said cleaning unit at least partially suspended from said second flexible, elongate member, and a second lateral side of said cleaning unit opposite said first lateral side moved vertically by rotation of said second loop; and

wherein each of said first carriage and said second carriage includes a moving arrangement for rotating only one of said first loop and said second loop and a guiding arrangement for guiding rotation of the other of said first loop and said second loop.

6. The apparatus of claim **5** wherein each of said first carriage and said second carriage includes a shifting arrangement for shifting said respective carriage laterally across the building.

7. The apparatus of claim **1** wherein said positioning unit further comprises:

at least one flexible, elongate member wherein said cleaning unit is at least partially suspended from said at least one flexible, elongate member; and

at least one tensioning unit mounted on said cleaning unit and configured to inhibit slack in said at least one flexible, elongate member.

8. The apparatus of claim **7** further comprising:

a conduit configured to deliver fluid to said cleaning unit, wherein said tensioning unit includes a cylinder in fluid communication with said conduit.

9. The apparatus of claim **8** wherein:

said at least one flexible, elongate member is further defined as first and second flexible, elongate members disposed on opposite sides of the cleaning unit; and

said at least one tensioning unit is further defined as first and second tensioning units disposed on opposite sides of the cleaning unit, both of said first and second tensioning units receiving fluid from said conduit.

10. The apparatus of claim **7** wherein said at least one tensioning unit further comprises:

a rod wherein said at least one flexible, elongate member extends through said rod.

11. The apparatus of claim **10** wherein said at least one tensioning unit is configured to wind said at least one flexible, elongate member about said rod to inhibit slack in said at least one flexible, elongate member.

12. The apparatus of claim **1** further comprising:

at least one extendible cylinder mounted on said cleaning unit, said cleaning agency mounted on said at least one cylinder, wherein said cleaning agency is urged toward the work surface by extension of said at least one cylinder and drawn away from the work surface by retraction of said at least one cylinder.

13. The apparatus of claim **12** wherein said positioning unit further comprises:

at least one flexible, elongate member wherein said cleaning unit at least partially suspended from said at least one flexible, elongate member and wherein said at least one flexible elongate member is urged away from the work surface by extension of said at least one cylinder.

14. The apparatus of claim **13** wherein said at least one flexible elongate member is further defined as including a plurality of said flexible elongate members and all of said flexible elongate members are urged away from the work surface by extension of said at least one cylinder.

15. The apparatus of claim **1** further comprising:

a conduit configured to deliver fluid to said cleaning unit; and

at least one cylinder engaged with said cleaning agency and extendable to urge said cleaning agency toward the work surface, said at least one cylinder in fluid communication with said conduit.

16. The apparatus of claim **15** wherein said at least one cylinder is further defined as a plurality of cylinders including first and second cylinders positioned on a same lateral side of said cleaning unit.

17. The apparatus of claim **15** wherein said at least one cylinder is further defined as a plurality of cylinders including first and second cylinders positioned on opposite lateral sides of said cleaning unit.

18. The apparatus of claim **1** further comprising:

a moving device operably disposed between said cleaning unit and said cleaning agency whereby a distance separating said cleaning unit and said cleaning agency

in a vertically-extending plane transverse to both of said front side and said back side is variable.

19. The apparatus of claim **18** wherein said moving device further comprises:

at least one extendible cylinder mounted on said cleaning unit, said cleaning agency mounted on said at least one cylinder, wherein said distance increases during extension of said at least one cylinder and decreases during retraction of said at least one cylinder.

20. The apparatus of claim **19** wherein extension of said at least one cylinder occurs along only a horizontal axis in said vertically-extending plane.

21. The apparatus of claim **1** wherein:

said cleaning unit further comprises at least one truck;

said positioning unit further comprises at least one elongate member, wherein said at least one truck is mountable on said at least one elongate member; and

a said apparatus further comprises a camera mountable on said at least one truck.

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