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[54] **TUBE CLEANING SYSTEM**

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[52] **U.S. Cl.** .... **134/46**, 134/167 C, 15/317
[51] **Int. Cl.** **B08b 3/02**, B08b 9/02
[58] **Field of Search** .... 134/46, 57 R, 167 C, 168 C, 134/24; 15/317, 104.16

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Primary Examiner—Robert L. Bleutge

[57] **ABSTRACT**

In a tube cleaning system, a pair of long, straight, small diameter, thin wall lances extend in parallel from a common cleaning fluid manifold to a pair of spray discharge heads. The lances are automatically moved into, through, and out of a pair of heat exchanger tubes by a lance drive system. The lance drive system comprises structure for moving the lances through the tubes and for simultaneously applying straightening forces thereto, apparatus for controlling both the extent of movement of the lances and the flow of cleaning fluid through the lances, and circuitry for automatically reversing and re-reversing the direction of movement of the lances upon engagement of either lance with an obstruction in its respective tube. The lance drive system is mounted on a frame which includes structure for aligning the lances with a pair of heat exchanger tubes prior to each operating cycle of the tube cleaning system.

5 Claims, 7 Drawing Figures

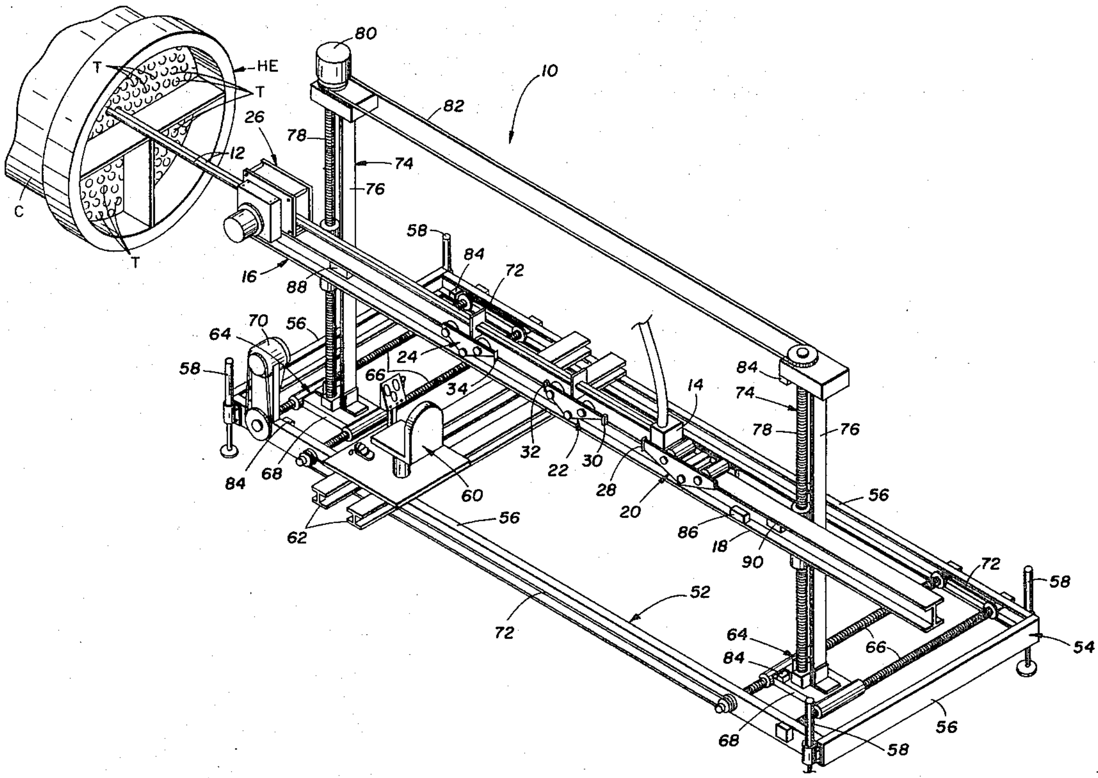
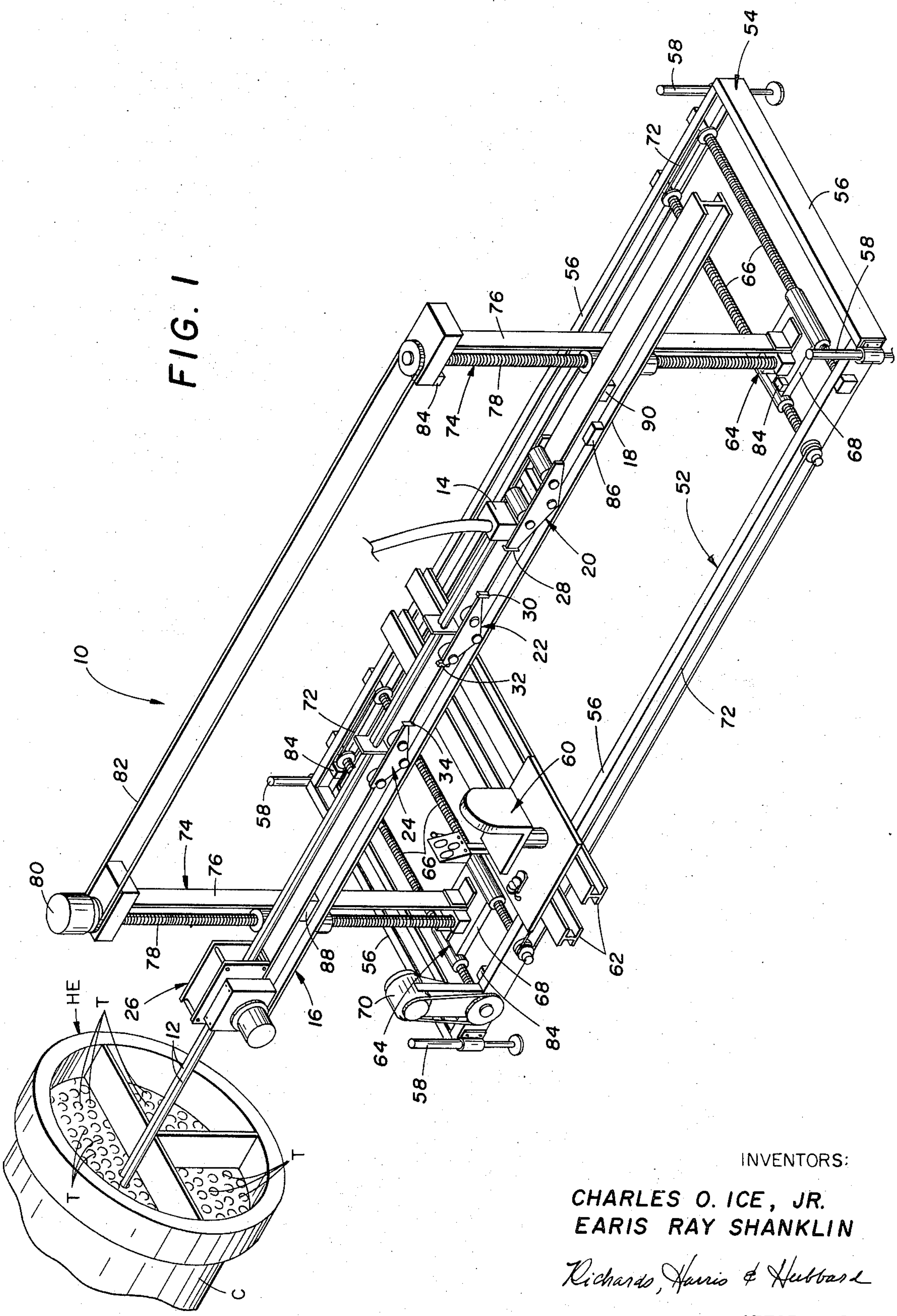


FIG. 1



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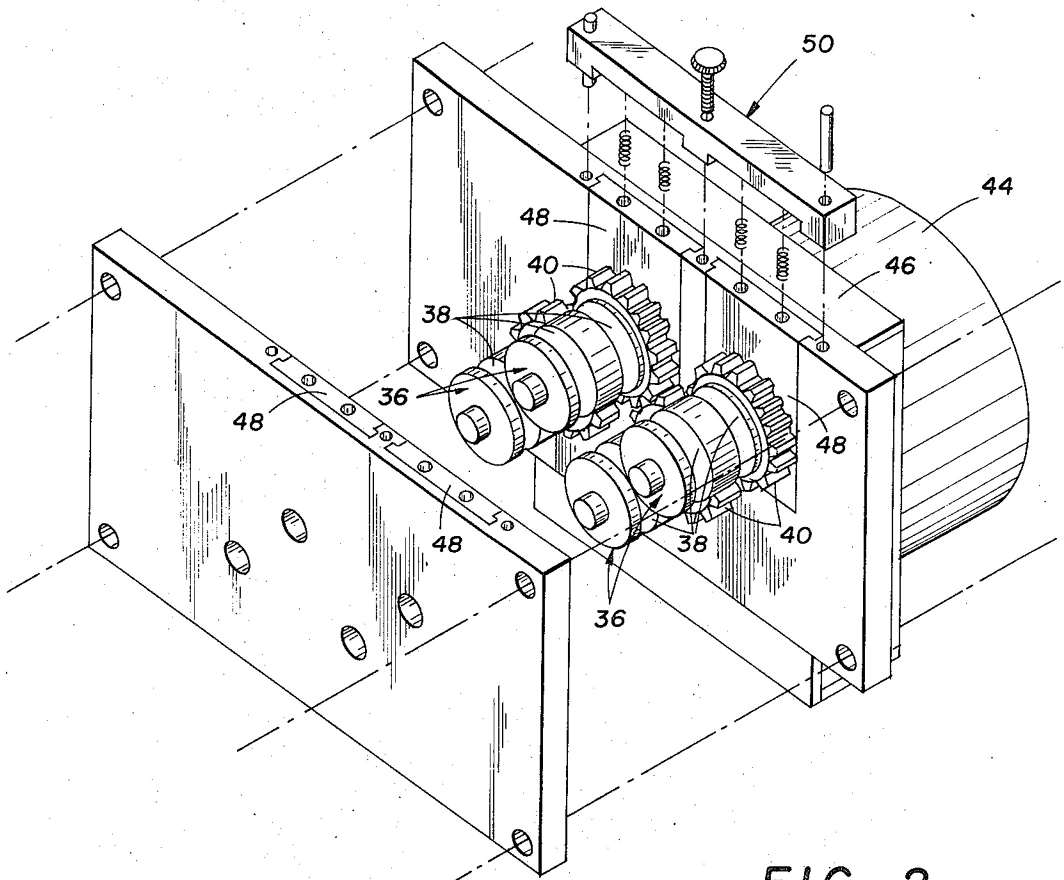

FIG. 2

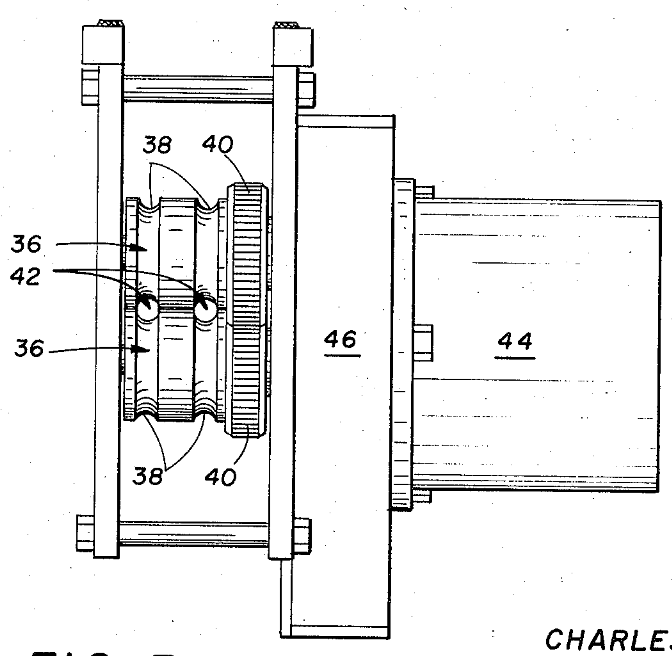

FIG. 3

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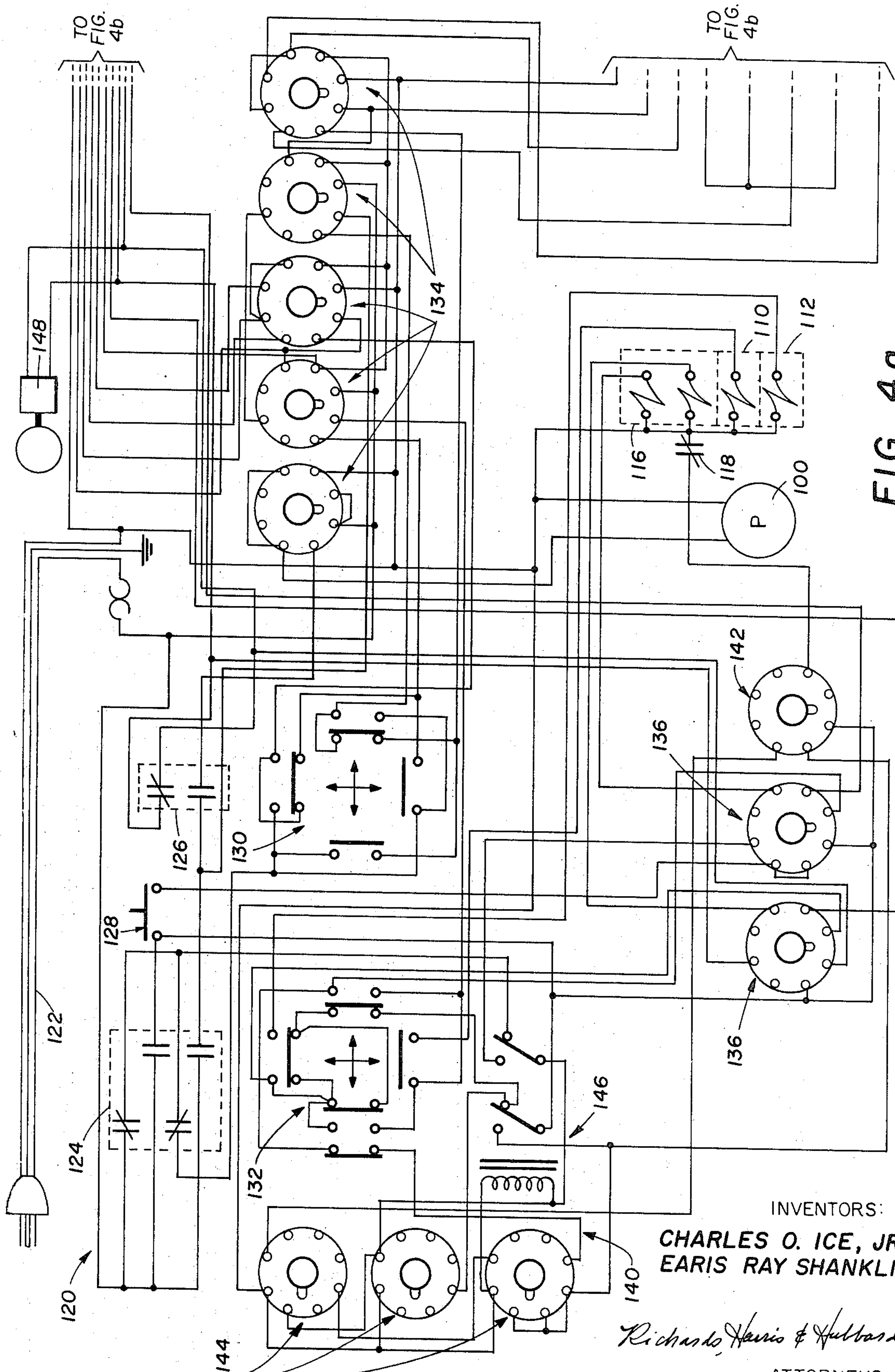

FIG. 4a

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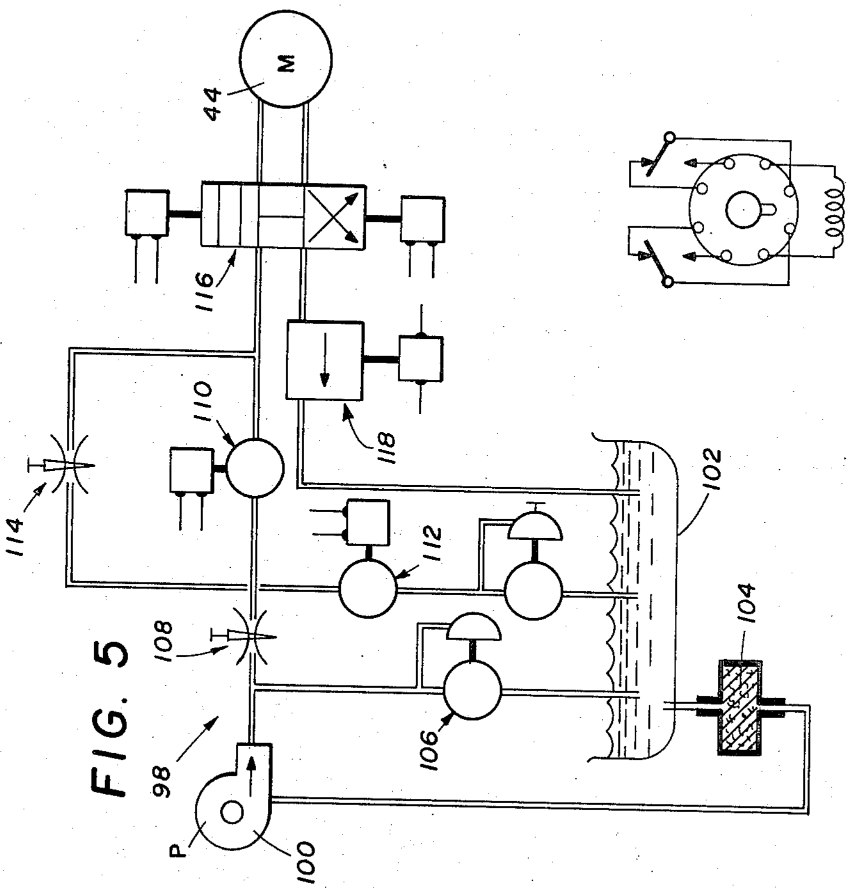
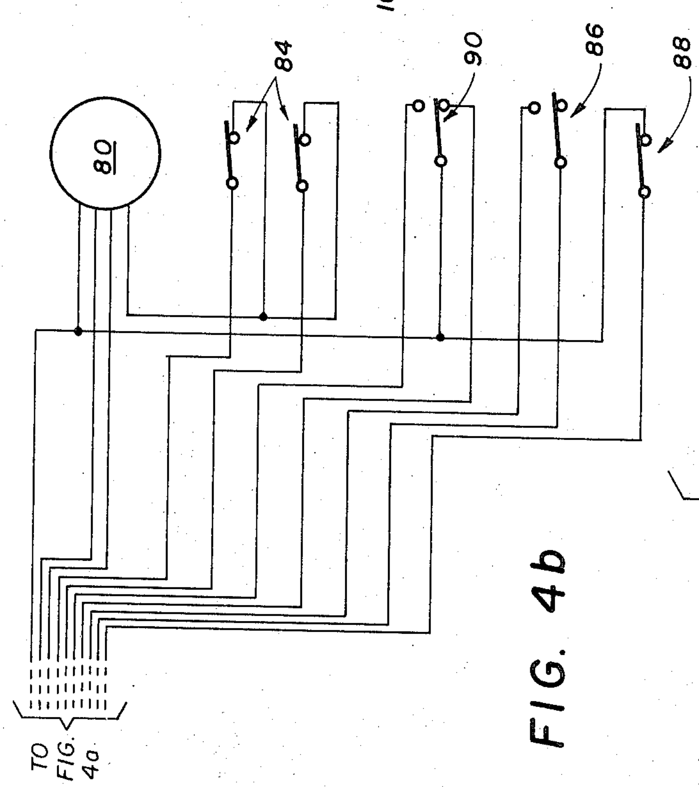


FIG. 5

FIG. 4c



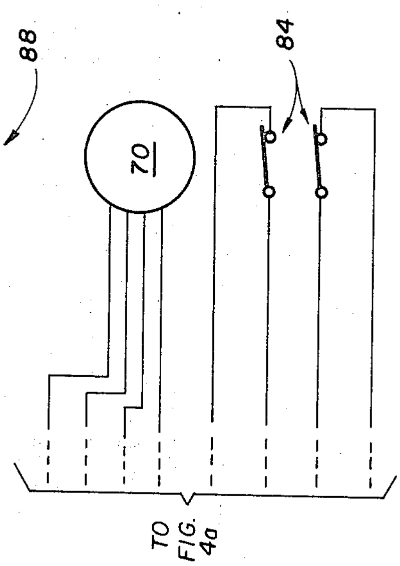


FIG. 4b

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TUBE CLEANING SYSTEM

BACKGROUND AND SUMMARY OF THE INVENTION

Heat exchangers are used throughout industry to transfer heat from one fluid to another. One type of heat exchanger includes a cylindrical outer shell and a tube bundle positioned within the shell. In the use of this type of heat exchanger, one fluid is passed through the tubes from one end of the shell to another. Another fluid is passed through the central portion of the shell around the tubes to achieve heat transfer between the fluids.

The fluids flowing through the tubes of a heat exchanger are often corrosive in nautre, and often contain dissolved solids, dirt, grease, etc. Any of these conditions can cause tubes of a heat exchanger to become clogged with solid materials. Any significant accumulation of solid materials in the tubes of a heat exchanger reduces the operating efficiency of the heat exchanger, and therefore necessitates cleaning of the interiors of the tubes.

Heretofore, the cleaning of the interiors of heat exchanger tubes has been manual in nature. For example, in accordance with a tube cleaning process that is currently in use, a small diameter, thin wall length of pipe known as a lance is manipulated manually through the interior of a heat exchanger tube. As the lance is moved through the tube, water is forced through the lance and out of the distal end thereof to clean the interior of the tube. If an obstruction is encountered, the lance is manuevered back and forth in the tube until the obstruction has been cleared from the tube. After the tube is clean, the lance is removed from the tube and is manually aligned with an adjacent tube for manipulation therethrough.

Manual heat exchanger tube cleaning systems are unsatisfactory for a number of reasons. For example, manual systems are generally slow in operation. Manual systems are also inefficient because the manual positioning of a tube cleaning lance in alignment with a heat exchanger tube typically requires the use of at least three workmen. Finally, due to their small diameter, thin wall nature, tube cleaning lances are easily bent, especially upon contact with an obstruction in a tube. When this occurs, it is often necessary to straighten the lance before proceeding with a cleaning operation.

The present invention relates to an automated system for cleaning the interiors of heat exchanger tubes. In accordance with the preferred embodiment of the invention, a pair of lances are aligned with a pair of heat exchanger tubes, and are then advanced into the tubes. As the lances enter the tubes, a cleaning fluid is forced through the lances from a common cleaning fluid manifold. The lances are normally advanced the entire length of the tubes and are thereafter automatically retracted out of the tubes. However, if an obstruction is encountered in one of the tubes, the direction of movement of the lances is automatically reversed and rereversed until the obstruction is cleared. Preferably, the lances are driven by a mechanism that applies straightening forces to the lances during their movement into and out of the tubes.

DESCRIPTION OF THE DRAWINGS

A more complete understanding of the invention may be had by referring to the following Detailed Description when taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is a perspective view of a tube cleaning system employing the invention;

FIG. 2 is an exploded view of the lance drive mechanism of the tube cleaning system shown in FIG. 1;

FIG. 3 is an end view of the lance drive mechanism;

FIG. 4*a* is a schematic illustration of a portion of an electrical circuit employed in the tube cleaning system shown in FIG. 1;

FIG. 4*b* is a schematic illustration of the remainder of the electrical circuit;

FIG. 4*c* is a schematic illustration of a relay that is employed in the electrical circuit, and

FIG. 5 is a schematic illustration of a hydraulic circuit employed in the tube cleaning system.

DETAILED DESCRIPTION

Referring now to the drawings, and particularly to FIG. 1 thereof, a tube cleaning system **10** employing the present invention is shown positioned adjacent a heat exchanger HE. The heat exchanger HE is conventional in design in that it is comprised of an outer cylindrical shell C and a plurality of tubes T which extend axially through the shell C. The function of the tube cleaning system **10** is to clean the interiors of the tubes T, that is to remove accumulations of solid materials that may be present within the interiors of the tubes.

The tube cleaning system **10** includes a pair of lances **12** which extend in parallel from a common cleaning fluid manifold **14** to a pair of conventional discharge nozzles (not shown). Typically, the lances **12** are about 20 feet in length and are about ⅜ inches in diameter. In order to provide maximum cleaning fluid flow into the interiors of the heat exchanger tubes, the lances **12** are preferably fabricated from thin wall pipe. This long, small diameter, thin wall lance construction has been found to be highly advantageous for heat exchanger cleaning purposes, however, it also renders the lances **12** extremely liable to bending and other damage. Thus, it is necessary to protect the lances **12** against bending, etc. during the operation of the tube cleaning system **10**.

To this end, the tube cleaning system **10** includes a lance drive assembly **16** which functions to move the lances **12** into and out of the heat exchanger tubes, and also to protect the lances **12** against damage. The lance drive assembly **16** includes an I-beam **18** which is preferably somewhat longer than the lances **12**. The lances **12** are supported for movement along the I-beam **18** by a rear lance support mechanism **20**, a pair of intermediate lance support mechanisms **22** and **24**, and a lance drive mechanism **26**.

The rear lance support mechanism **20** includes a plurality of rollers which engage the upper and lower sides of the upper flange of the I-beam **18**, and serve to support the common cleaning fluid manifold **14** and the ends of the lances **12** extending therefrom. The intermediate lance support mechanisms **22** and **24** also comprise rollers which engage the upper flange of the I-beam **18**, and serve to support the intermediate portions of the lances **12**. During movement of the lances **12** in the direction of the lance drive mechanism **26**, the rear lance support mechanism 20 moves with the lances 12 until a plate 28 on the mechanism 20 engages a magnet 30 on the mechanism 22, whereupon both the mechanism 20 and the mechanism 22 move with the lances 12. This movement continues until a magnet 32 on the forward end of the mechanism 22 engages a plate 34 on the mechanism 24, whereupon all three lance support mechanisms move forwardly with the lances 12.

During movement of the lances 12 toward the end of the I-beam 18 remote from the lance drive mechanism 26, the rear lance support mechanism 20 is moved rearwardly with the lances 12, and the magnets 30 and 32 on the intermediate lance supporting mechanism 22 connect the intermediate lance supporting mechanisms 22 and 24 to the rear lance supporting mechanism 20 for movement therewith. This movement continues until the mechanism 24 engages a first fixed stop (not shown). Engagement of the mechanism 24 with the first stop breaks the magnetic connection between the magnet 32 and the plate 34, whereupon the mechanism 24 remains stationary and the mechanism 22 continues to move with the mechanism 20. Subsequentially, the mechanism 22 engages a second fixed stop (also not shown). Engagement of the mechanism 22 with the second stop breaks the magnetic connection between the magnet 30 and the plate 28 whereupon only the mechanism 20 moves with the lances 12. It will be understood that the fixed stops are so located on the I-beam 18 that the portions of the lances 12 located between the lance drive mechanism 26 and the rear lance support mechanism 24 are adequately supported at all times.

The structural details of the lance drive mechanism 26 of the lance drive assembly 16 are illustrated in FIGS. 2 and 3. Referring first to FIG. 2, the mechanism 26 comprises four rollers 36 each comprising a pair of lance receiving grooves 38 and a gear 40. As is best shown in FIG. 3, the rollers 36 are so arranged that the grooves 38 combine to form a pair of circular lance receiving channels 42. The gears 40 of the rollers 36 are mounted in meshing interengagement and one of the rollers is driven by a hydraulic motor 44 through a speed reducer 46. By this means, the rollers 36 drive the lances 12 into and out of the tubes of a heat exchanger.

As is best shown in FIG. 2, the rollers 36 are positioned at spaced points axially of the lances 12, and alternate rollers 36 are positioned on opposite sides of the lances 12. The upper two rollers 36 are mounted on a pair of slides 48, and a pair of adjusting mechanisms 50 (only one of which is shown) are provided for controlling the pressure that is applied to the lances 12 by the rollers 36. Due to the foregoing construction, the drive mechanism 26 applies straightening forces to the lances 12 during the movement thereof. By this means, any tendency of the lances to bend under the action of gravity or otherwise during the use of the tube cleaning system 10 is continuously corrected by the drive mechanism 26, and the lances 12 are therefore maintained perfectly straight.

Referring again to FIG. 1, the lance drive assembly 16 is supported in a frame 52. The frame 52 includes a rectangular main frame 54 comprising four interconnected box beams 56 that are supported on four hydraulic cylinders 58. The main frame 54 supports an operator's station 60 which is mounted on a pair of beams 62 for horizontal movement relative to the frame 54.

The main frame 54 also supports a pair of horizontal locating assemblies 64. Each horizontal locating assembly 64 includes a pair of lead screws 66 and a platform 68 mounted on the lead screw 66 for horizontal movement relative to the frame 54. The lead screws 66 are selectively rotated by an electric motor 70 and are interconnected by a plurality of chains 72. Thus, upon operation of the motor 70, the platforms 68 of the horizontal locating assemblies 64 are moved in sychronism to position the lances 12 horizontally relative to the frame 54.

The platforms 68 of the horizontal locating assembly 64 support a pair of vertical locating assemblies 74. The vertical locating assemblies 74 each include a beam 76 which extends upwardly from one of the platforms 68 and which supports a lead screw 78. The lead screws 78 are selectively rotated by an electric motor 80 and are interconnected by a chain 82. The I-beam 18 of the lance drive assembly 16 is supported on the lead screws 78 for vertical movement upon rotation thereof. Thus, upon actuation of the motor 80, the lances 12 are positioned vertically relative to the tubes of a heat exchanger.

In the use of the tube cleaning system 10, the axes of the lances 12 are brought into alignment with the axes of the tubes of a heat exchanger, preferably by operating the hydraulic cylinders 58 to level the main frame 54. Thereafter, the horizontal locating assemblies 64 and the vertical locating assemblies 74 of the frame 52 are actuated to bring the lances 12 into alignment with a particular pair of tubes T in the heat exchanger. The tube cleaning system 10 is equipped with a plurality of limit switches 84 which prevent actuation of the horizontal positioning mechanism 64 and the vertical positioning mechanisms 74 beyond the limits imposed by the size of the frame 52.

When the lances 12 are properly positioned, the lance drive assembly 16 is actuated to move the lances 12 into, through, and out of the selected pair of tubes in the heat exchanger. The lance drive assembly 16 is provided with three limit switches 86, 88 and 90 which control the flow of cleaning fluid through the lances 12, the extent of inward movement of the lances 12, and the extent of outward movement of the lances 12, respectively. The limit switches 86, 88 and 90 are preferably mounted for selective positioning on the I-beam 18 of the lance drive system 16 in accordance with the physical size of a particular heat exchanger and in accordance with the location of the heat exchanger relative to the tube cleaning system 10.

The operation of the lance drive assembly 16 in moving the lances 12 into and out of a pair of heat exchanger tubes is controlled by electric and hydraulic circuits of the type illustrated in FIGS. 4 and 5, respectively. Referring first to FIG. 5, a hydraulic circuit 98 for operating the motor 44 of the lance drive mechanism 26 in forward and reverse directions and at high and low speeds is schematically shown. The circuit 98 includes a pump 100 which draws hydraulic fluid from a sump 102 through a filter 104. A relief valve 106 controls the pressure of the circuit 98, and a needle valve 108 provides adjustment of the high speed operation of the motor 44. A pair of normally open, solenoid operated valves 110 and 112 are selectively closed for low speed operation and high pressure operation, respectively. A needle valve **114** provides adjustment of the low speed operation of the motor **44**.

The hydraulic circuit **98** further includes a three position, four way, solenoid operated valve **116** which is actuated by the electrical circuit of the tube cleaning system **10** to control the direction of flow of hydraulic fluid from the pump **100** to the motor **44**. A pressure responsive switch **118** is located in the return line from the motor **44** and is responsive to a predetermined decrease in the return line pressure to generate an electrical signal. Since the return line pressure from the motor **44** tends to decrease as the motor stalls, a signal from the switch **118** indicates interference with the movement of at least one of the lances **12**.

Referring now to FIGS. *4a*, *4b* and *4c*, an electrical circuit **120** that is employed to control various functions of the lance drive assembly **16** is schematically illustrated. The circuit **120** comprises a plurality of identical relays, one of which is shown in FIG. *4c*. That is, each relay in the circuit **120** comprises two normally closed contact pairs which are opened upon energization of the relay, two normally open contact pairs which are closed upon energization of the relay, and a relay coil, and the various components of each relay are connected to terminal pins in the manner illustrated in FIG. *4c*.

Referring now to FIGS. *4a* and *4b*, conventional 115 Volt 60 Hertz line current is directed to the circuit **120** through a power cord **122**. A pair of three position switches **124** and **126** provide main power control and pump power control, respectively. A pushbutton **128** is selectively actuated to begin automatic operation of the tube cleaning system **10**.

A pair of switches **130** and **132** are mounted for manual operation from the operator's station **60** of the tube cleaning system **10**. The switch **130** cooperates with the limit switches **84**, the limit switch **90**, and a plurality of relays **134** to control the operation of the motors **70** and **80**. That is, upon operation of the switch **130**, the horizontal and vertical locating assemblies are selectively actuated to adjust the horizontal and vertical positioning of the lances **12**. The switch **130** and the limit switch **90** are preferably interconnected in such a way that the horizontal and vertical positioning assemblies **64** and **74** cannot be actuated except when the lances **12** are fully retracted.

The switch **132** cooperates with the limit switches **88** and **90** and with a plurality of relays **136** to control the direction and speed of operation of the motor **44** of the lance drive mechanism **26**.Also, the switch **132** operates through the solenoid operated valve **130** of the hydraulic circuit **98** to selectively apply high pressure to the motor **44**. The latter function is preferably interconnected with the direction control function of the switch **132** in such a way that high pressure can only be applied to retract the lances **12**. It should be noted that the application of high pressure to the motor **44** is not required in the normal operation of the tube cleaning system **10**, and is only required in the event the lances **12** become stuck in the tubes of a heat exchanger.

The electrical circuit **120** further includes a subcircuit **140** including the pressure sensitive switch **118** of the hydraulic circuit **98**, a relay **142** that is energized in response to closure of the switch **118**, a plurality of time delay switches **144** that are sequentially operated in response to energization of the relay **142**, and a relay **146** that is actuated in response to operation of one of the switches **144**. Upon engagement of either of the lances **12** with an obstruction or other interference in one of the tubes of a heat exchanger, the subcircuit **140** immediately reverses the direction of movement of the lances **12**. When the lances have moved a short distance in the reverse direction, lance movement is stopped for a brief period of time so that cleaning fluid flowing through the lances can remove the obstruction, etc. Then, the direction of movement of the lances is re-reversed, that is, movement of the lances **12** through the tubes is re-initiated. If the tubes have been cleared of all obstructions, the lances continue to move through the tubes without further operation of the subcircuit **140**. If however, the same or another obstruction is encountered, the subcircuit **140** again operates to reverse and then re-reverse the direction of movement of the lances until all obstructions are cleared from the tubes.

OPERATION

Initially, the tube cleaning system **10** is positioned adjacent a heat exchanger to be cleaned. It has been found that if the major structural components of a tube cleaning system employing the invention are fabricated from aluminum, the system is easily manipulated by four workmen. The tube cleaning system is then connected to the heat exchanger, preferably by rods connected between the heat exchanger and the frame **52** of the tube cleaning system. As previously indicated, the lances are then aligned with the axes of the tubes of the heat exchanger by operating the hydraulic cylinders **58** of the frame **52**. Next, the horizontal and vertical locating assemblies **64** and **74** are operated under the control of the switch **130** to position the lances **12** in alignment with a particular pair of tubes in the heat exchanger. A final check on the alignment of the lances **12** is achieved by operating the switch **132** to advance the lances **12** very slowly toward the selected pair of tubes.

When the lances **12** are properly aligned, the pushbutton **128** is actuated to begin operation of the tube cleaning system **10**. Thereafter, the lance drive assembly **116** operates under control of the limit switches **88** and **90** to advance the lances **12** into and through the selected pair of tubes, and to thereafter retract the lances **12** out of the tubes. During this action, the limit switch **86** initiates the flow of cleaning fluid through the lances **12** upon entry of the lances **12** into the tubes, and terminates the flow of cleaning fluid through the lances **12** upon withdrawal of the lances from the tubes. As is shown in FIG. *4a*, the latter function is accomplished by means of a solenoid controlled device **148** that controls the flow of cleaning fluid through the common cleaning fluid manifold **14** and into the lances **12**.

If either of the lances **12** encounters any obstruction or other interference in a tube of the heat exchanger, the switch **118** closes, whereupon the subcircuit **140** immediately terminates lance movement. This is very important in that it prevents bending of the lances due to the application of excessive compressive forces. Thereafter, the subcircuit **140** actuates the lance drive mechanism **26** to withdraw the lances **12** a short distance in order to permit the cleaning fluid flowing through the lances to dislodge the interfering matter from the interior of the tube. Finally, lance movement in the original direction is re-initiated by the subcircuit

140, and is continued subject to termination by the subcircuit 140 in the event either lance encounters interference.

It will be understood that due to the extremely long, small diameter, thin wall construction of the lances 12, the lances are subjected to bending forces throughout the operation of the tube cleaning system 10. To this end, the portions of the lances 12 extending between the rear lance support mechanism 20 and the lance drive mechanism 26 are supported by the intermediate lance support mechanisms 22 and 24. Also, the lance drive mechanism 26 applies straightening forces to the lances 12 throughout the movement of the lances 12 into and out of the tubes of a heat exchanger. The latter function is very important in that it assures the straightness of the lances 12 throughout the operation of the tube cleaning system 10.

Upon completion of the movement of the lances 12 into and out of the selected pair of tubes, the horizontal and vertical locating assemblies 64 and 74 are actuated to position the lances 12 in alignment with a second pair of tubes in the heat exchanger. Then, another automatic cycle of the tube cleaning system 10 is initiated by depressing the pushbutton 128. When all of the tubes of the heat exchanger have been cleaned, the tube cleaning system 10 is moved into alignment with another heat exchanger, and the foregoing process is repeated.

It will be understood that various substitutions and modifications can be made in the structure of the tube cleaning system shown in the drawings. For example, an internal combustion engine can be employed as the basic prime mover in the system. Similarly, the hydraulic motor 44 of the lance drive system 26 can be replaced with an electric motor, and the electric motors 70 and 80 of the horizontal and vertical locating assemblies 64 and 74 can be replaced with hydraulic motors. Other substitutions that will be readily apparent to those skilled in the art include the use of equivalent fluidic, pneumatic or electronic control circuits in place of the electrical and hydraulic control circuits that have been disclosed.

Perhaps more importantly, there are several mechanisms that can be employed in lieu of the pressure sensitive switch 118 to detect interference with the movement of the lances 12 through the tubes of a heat exchanger. One such alternative mechanism comprises a tachometer or other speed responsive apparatus positioned to sense either the rotational speed of the rollers 136 or the speed of advance of the lances 12. Another alternative mechanism comprises strain gauges positioned to detect the magnitude of the compressive forces that are applied to the lances 12 by the lance drive mechanism 26. Still another alternative mechanism comprises a torque meter responsive to the torque that is imposed on the rollers 36 by the motor 44. Other mechanisms for detecting resistance to the movement of the lances through the tubes of a heat exchanger will occur to those skilled in the art, and any of the alternative mechanisms may be employed in the tube cleaning system 10 instead of or in addition to the pressure sensitive switch 118, if desired.

From the foregoing, it will be understood that the present invention relates to a tube cleaning system in which a pair of lances are automatically moved into, through, and out of heat exchanger tubes. Preferably, straightening forces are applied to the lances as they are moved, and the movement of the lances is automatically reversed and then re-reversed whenever either lances encounters interference. The use of the invention is advantageous over the use of manual tube cleaning systems in that it cleans the tubes of a heat exchanger considerably more rapidly than is possible with manual systems, and in that after a tube cleaning system employing the invention has been positioned adjacent a heat exchanger, the system can be operated by a single workman. Also, the features of the present invention relating to the application of straightening forces to the lances and to the termination of lance movement whenever either lance encounters interference combine to completely eliminate the problem of lance bending.

Although a particular embodiment of the invention has been illustrated in the drawings and described in the foregoing specification, it will be understood that the invention is not limited to the embodiment disclosed, but is capable of rearrangement, modification and substitution of parts and elements without departing from the spirit of the invention.

What is claimed is:

1. In a system for cleaning the interior of a heat exchanger tube, the improvement comprising:
- means for advancing a tube cleaning lance into the interior of a heat exchanger tube;
- means responsive to movement of the lance into the tube for directing a cleaning fluid through the lance and into the tube;
- means responsive to the movement of the lance through the entire length of the tube for retracting the lance out of the tube,
- means for applying straightening forces to the lance during the advancing and retracting movements thereof, and
- means for positioning the lance in alignment with a heat exchanger tube and means for preventing actuation of the positioning means when the lance is positioned within the interior of a heat exchanger tube.

2. A tube cleaning system comprising:
- a tube cleaning lance having an axis;
- means for locating the lance in mutually perpendicular directions relative to its axis and thereby aligning the lance with various tubes to be cleaned;
- means for moving the lance axially and thereby reciprocating the lance into and out of the tubes;
- means for sensing resistance to movement of the lance through a tube;
- means responsive to the sensing of a predetermined resistance for reversing the direction of movement of the lance relative to the tube;
- means for subsequently re-reversing the direction of movement of the lance; and
- means for preventing operation of the lance locating means whenever the lance is reciprocated into a tube.

3. The tube cleaning system according to claim 2 wherein the lance movement direction reversing means comprises means for moving the lance in the reverse direction to a retracted position, and wherein the lance direction of movement re-reversing means comprises means for maintaining the lance in the retracted position for a predetermined period of time.

4. A tube cleaning system comprising:
- a tube cleaning lance having an axis;

means for locating the lance in mutually perpendicular directions relative to its axis and thereby aligning the lance with various tubes to be cleaned;

means for moving the lance axially and thereby reciprocating the lnace into and out of the tubes;

means for directing a cleaning fluid through the lance and into a tube whenever the lance is positioned in the tube; and

means for preventing operation of the lance locating means whenever the lance is reciprocated into a tube.

5. A tube cleaning system comprising:

a pair of elongate, straight, tube cleaning lances each having an axis;

means for supporting the lances and for reciprocating the lances into and out of a pair of tubes to be cleaned;

a frame;

front and rear vertical positioning mechanisms for moving the lance support and reciprocating means vertically relative to the frame;

front and rear horizontal positioning mechanisms for moving the lance support and reciprocating means horizontally relative to the frame;

means for orienting the frame and thereby aligning the lances with the tubes;

means responsive to the axial positioning of the lances for preventing operation of the vertical and horizontal positioning mechanisms whenever the lances are reciprocated into the tubes;

means for maintaining the straightness of the lances during reciprocation thereof into and out of the tubes;

means responsive to movement of the lances into the tubes for directing a cleaning fluid through the lances and into the tubes;

means responsive to interference with the movement of either lance for terminating the movement of the lances into the tubes; and

means responsive to movement of the lances through the entire lengths of the tubes for initiating retraction of the lances out of the tubes.

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