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Wulc

[11] **3,892,282**
[45] **July 1, 1975**

[54] RANDOM MOTION SUCTION CLEANER

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[73] Assignee: **Total Enterprises, Inc.**, Hatboro, Pa.

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Related U.S. Application Data

[62] Division of Ser. No. 28,453, April 14, 1970, Pat. No. 3,676,774.

[52] **U.S. Cl.** **180/6.5**; 180/79
[51] **Int. Cl.** **B62d 11/04**
[58] **Field of Search** .... 180/6.5, 79, 79.1, 6.28, 180/2, 98; 15/1.7; 56/10.2; 46/244 R

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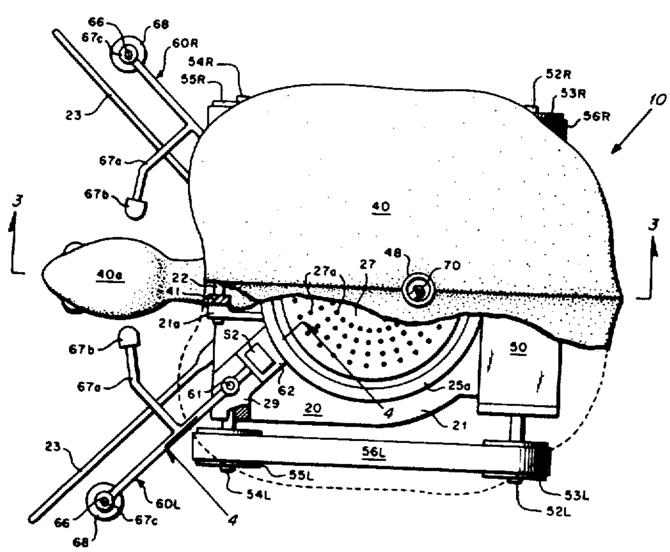
Assistant Examiner—John A. Pekar
Attorney, Agent, or Firm—Paul Maleson

[57] **ABSTRACT**

A self-propelled device adapted to move along the bottom of swimming pools or other water tanks in a random pattern to clean the surface thereof. The cleaner has low-voltage motors for driving, sensing means to sense contact with walls, and electronic logic means to direct the motion of the cleaner according to certain requirements. The cleaner has a suction inlet, a strainer, and is connected by means of a hose to a relatively high-voltage pump above the water level. The logic means provides for lock-out of spurious signals, pause times, and turning by selected drive wheel reversals. Various modifications and broad applications of certain of the principles are possible.

4 Claims, 9 Drawing Figures



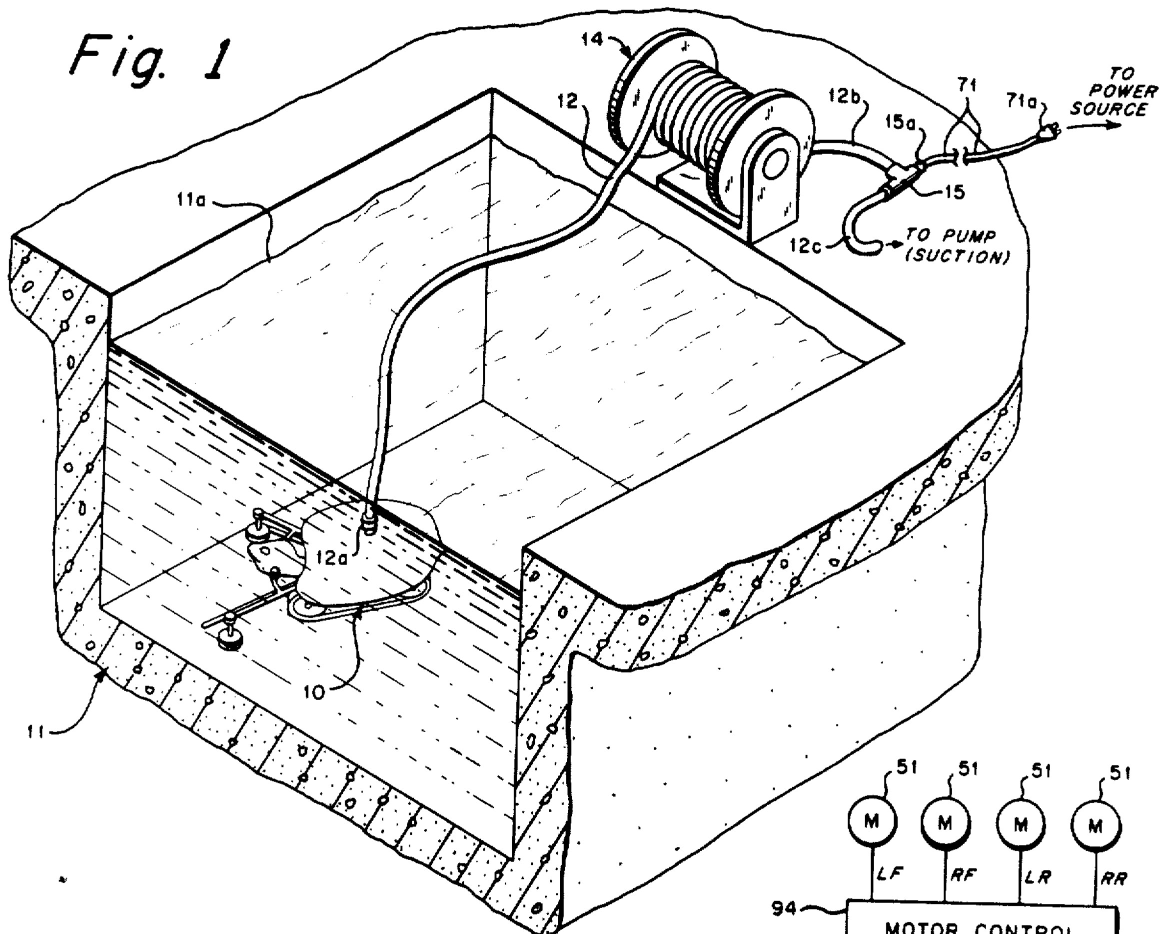


Fig. 1

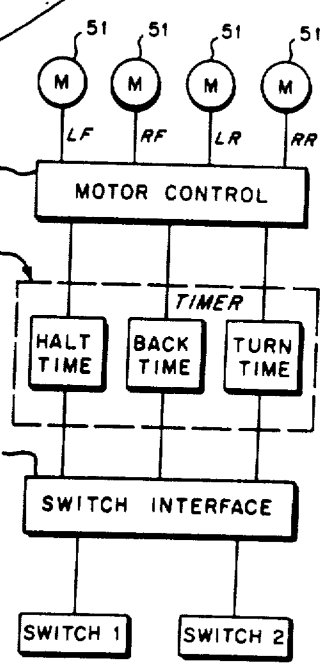


Fig. 5a

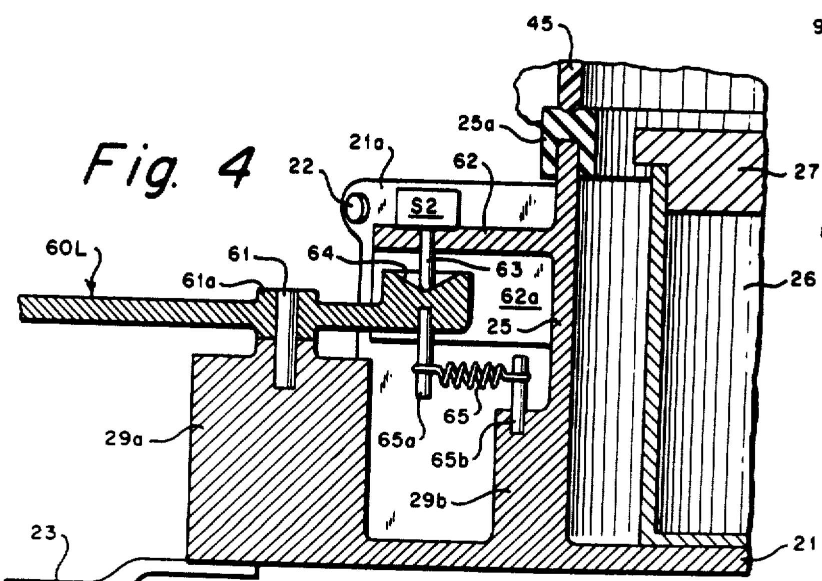
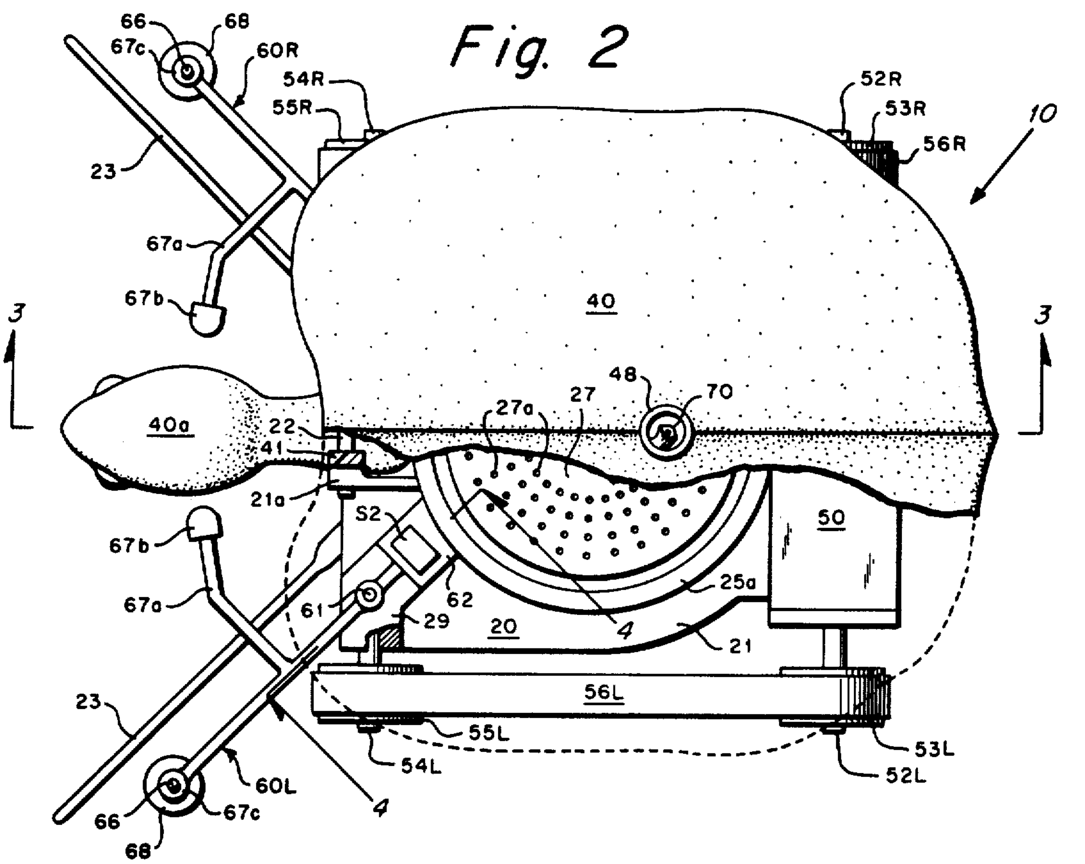


Fig. 4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68
67c
60R
54R
55R
52R
53R
56R
10
23
67a
67b
3
40
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70
27
27a
40a
22
41
21a
S2
50
67b
25a
62
67a
61
29
20
4
21
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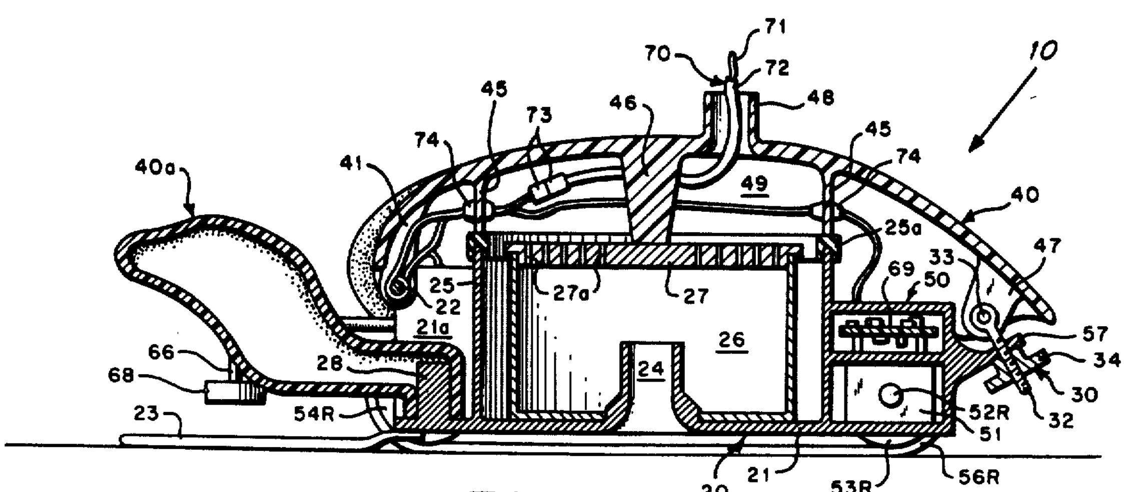
23
55L
53L
54L
52L
60L
4
66
67c
68

Fig. 2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73
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40a
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74
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25a
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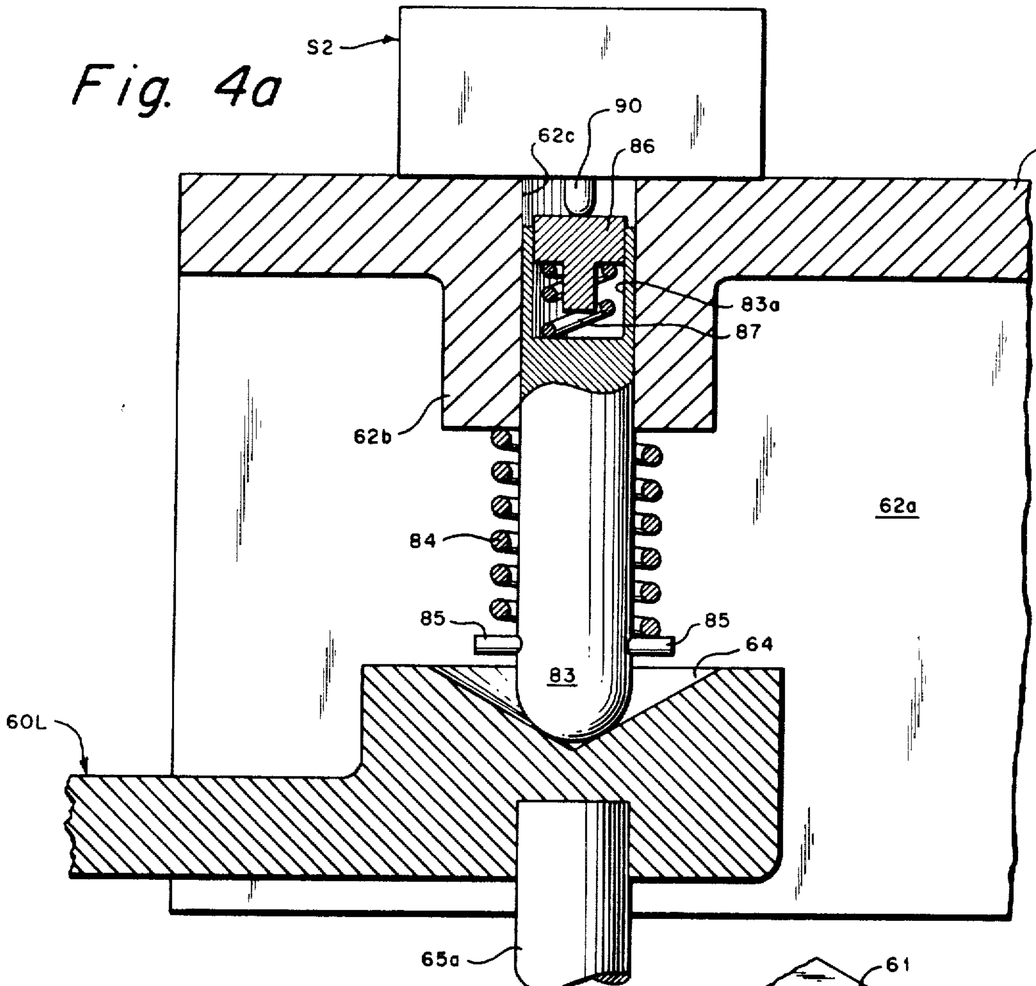
69
50
22
27a
27
57
21a
26
34
66
28
24
30
68
52R
54R
32
23
51
20
21
53R
56R

Fig. 3

Fig. 4a



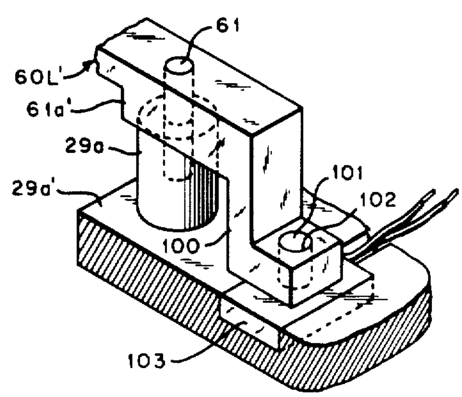
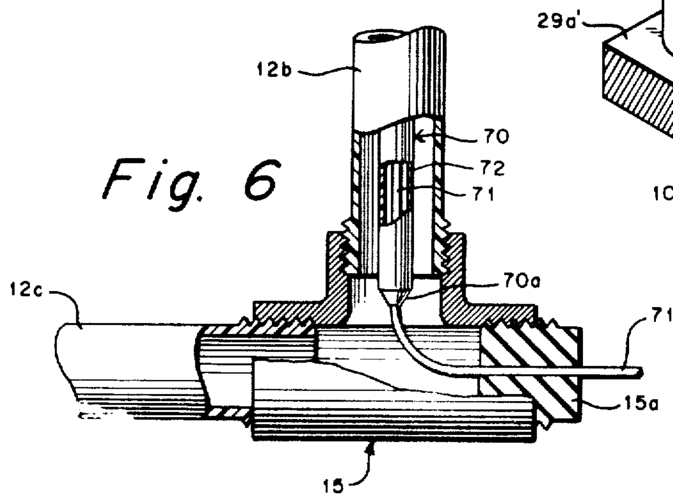


Fig. 7

Fig. 6



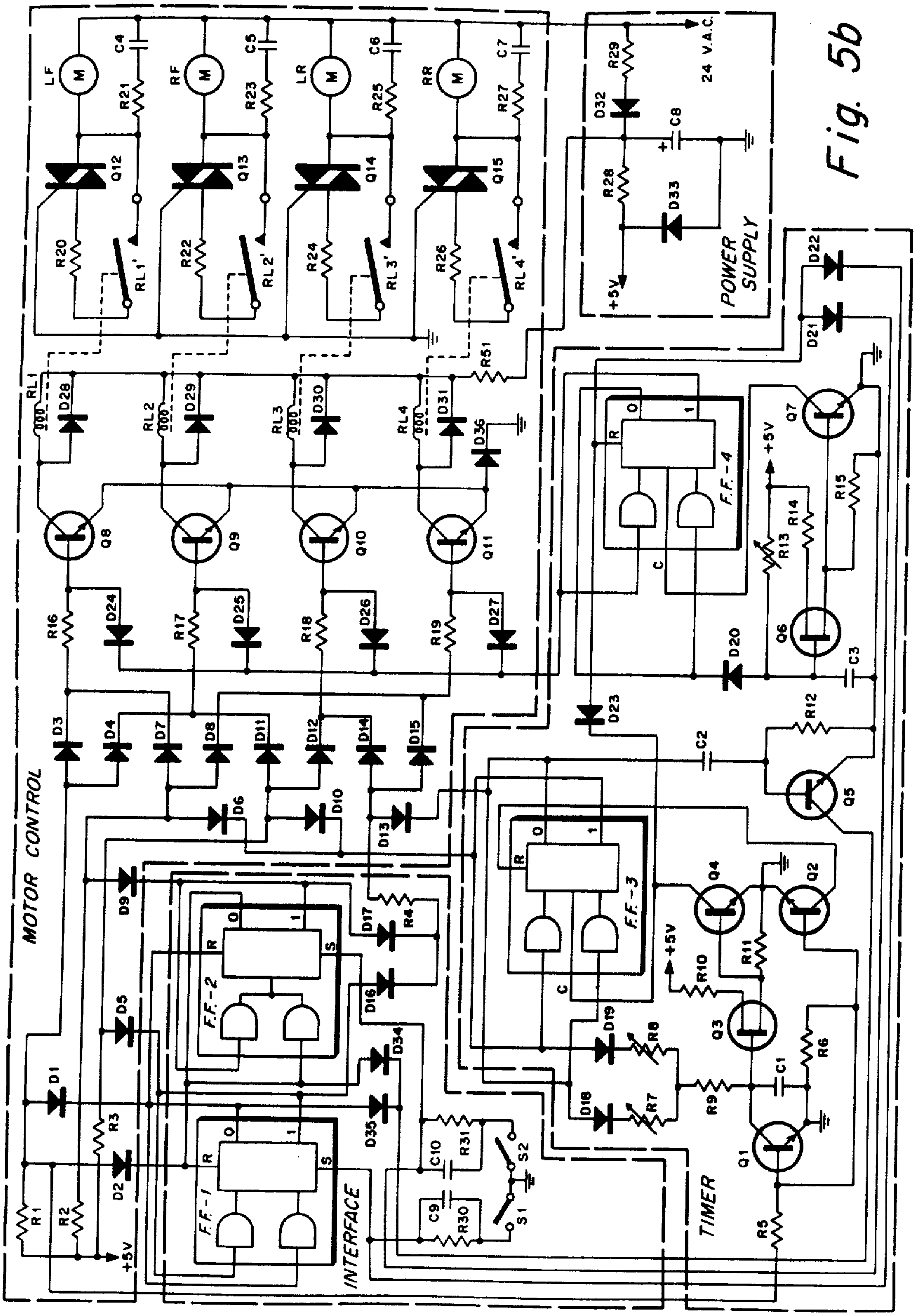

MOTOR CONTROL
INTERFACE
TIMER
POWER SUPPLY
24 V.A.C.
LF
RF
LR
RR
F.F.-1
F.F.-2
F.F.-3
F.F.-4
+5V

Fig. 5b

RANDOM MOTION SUCTION CLEANER

This is a division of application Ser. No. 28,453, filed Apr. 14, 1970 now U.S. Pat. No. 3,676,774.

BACKGROUND OF THE INVENTION

1. Field of the Invention

In its basic or exemplary form, this invention relates to a random motion suction cleaner for swimming pool bottoms. It is required from time to time to clean such pool bottoms to remove debris and certain growths and other materials. Suction cleaners attached to hoses and handles are often used. Self-propelled devices have been known to perform this function.

While the preferred embodiment of this invention has been specifically developed and designed for use in swimming pools and for submerged service into other tanks, certain aspects of the drive, control, and logic of the device are suitable for broader application. Generally, such broader application involves a case in which it is desired to have a self-propelled device moving across a horizontal surface to cover it in a random pattern, and provide it with sensing means and logic and control means whereby the device senses obstructions and turns away from them to continue its motion in a random manner, with a high degree of effeciency and a minimization of the possibility of the device becoming trapped by certain configurations of the obstacles.

2. Description of the Prior Art

It is known to clean the submerged surfaces in tanks by suction means. It is known as a broad concept to provide devices adapted to move along surfaces in a random manner and to turn away from the boundaries of the selected surface. Such devices include lawn-mowing machines which sense electrically operated boundry markers. In the pool cleaning field, known expedients include such disclosures as in U.S. Pat. Nos. 2,923,954; 3,321,787; 3,324,492; 3,439,368; and Austrailan Pat. No. 9648/27. These citations are exemplary, not exhaustive.

The present invention has a number of advantages over prior expedients, particularly considering the earlier known random devices for cleaning the bottoms of swimming pools. Briefly stated, these advantages include the following by way of example: the present device uses much lower voltages below water, resulting in a very important safety factor. It eliminates the requirements of relatively heavy and cumbersome gears and other mechanical contrivances for providing the turning motion. It provides a much more sensitive and subtle program of response to its environment which significantly decreases the chances of the device being trapped in wall corners or near other specific configurations of wall and increases the probability of the thorough cleaning of the entire surface within statistical limitations. It provides stronger suction and hence better cleaning abilities because of its use of an above-water relatively high-voltage pump. It uses electronic logic and control means which are lighter, more compact, reliable, inexpensive, and capable of better control than those heretofore known. It utilizes certain elements of pre-existing structure associated with swimming pools, particularly, the pool skimming and filtration system pump. It is safer than previously known devices in other respects as well, as for example by its elimination of most rotating machinery.

SUMMARY

In its preferred illustrated form, this invention is a random motion suction cleaner for swimming pool bottoms. It also has obvious extension of applicability to submerged surface in other types of tanks. Broadly, some aspects of the invention, particularly the control and logic means are suitable for other applications, as has been described.

some of the advantages of the present invention over previously known expedients in this field have been set forth above in the discussion of the prior art.

It is an object of this invention to provide an electronic programmed drive control to automatically direct a vehicle across a surface in response to sensing of obstacles.

It is an object of this invention to provide a suction cleaner for submerged surfaces in tanks.

It is another object of this invention to provide a suction cleaner for the bottoms of swimming pools, adapted to move in a random pattern over the bottom surface and to sense the walls of the pool or other obstacles and to turn away from them.

The cleaner is provided with driving wheels directly operated by low-voltage motors. The drive wheels on a given side are each capable of forward and reverse motion. The vehicle includes a suction inlet and a removable strainer to catch large debris. The pumping means for the suction is provided independently of the vehicle above the water level and is connected to the vehicle by means of a hose. This permits the use of a more powerful suction pump with higher voltages without the necessity of introducing these voltages into the water, and also permits the use of pre-existing swimming pool filtration and skimming pumping and connection facilities. Means to float the hose or to reduce its adverage density compared with that of the water are provided.

The vehicle has gathering means for the bottom debris. It has right and left sensing means to operate switches when contact is made with a wall. These sensing means are constructed so as to minimize the possibility of anomalies or other instances of failure to respond. A completely electronic, completely solid-state, programmed logic and control means is provided. This logic and control means responds to contacts of the sensors with the wall and controls the motors according to a pre-selected logical program. Some important aspects of the control and drive structure are that the driving wheels are not steered, but instead their directions are fixed and all steering of the vehicle takes place by selective forward, reverse, and pause states in the rotation of the driving wheels; there is no gearing or other selective transmission means depended upon to engage or disengage the wheels from the motor means, and instead, the drive wheel or wheels on a given side of the vehicle are connected to a pair of motors, one of which is wired for forward motion and the other of which is wired for reverse motion; the duration of the various steps in the programmed cycle may be electronically adjusted.

The vehicle may be provided with a decorative sheath so as to resemble an attractive or amusing creature, such as a turtle.

BRIEF DESCRIPTION OF THEE DRAWINGS

FIG. 1 is a perspective view, partially and cross-section, of a swimming pool provided with the cleaning system.

FIG. **2** is a plan view of the vehicle, with the outside covering partially fragmented.

FIG. **3** is a cross-sectional view of the vehicle taken along line **3**—**3** of FIG. **2**.

FIG. 4 is a cross-sectional view taken along line **4**—**4** of FIG. 2 showing the connection between a sensing bar and a switch.

FIG. 4*a* is an enlarged detail elevation view, partially and cross-section of the override mechanism between the sensing bar and the switch.

FIG. 5*a* is a block diagram of the sensing, logic, control, and drive means of the vehicle.

FIG. 5*b* is a schematic of the means of FIG. 5*a*.

FIG. 6 is a detailed enlarged view, partially and cross-section, partially fragmented, of the upper termination of the hose.

FIG. 7 is a perspective view of a magnetic connection between a sensor arm and a magnetic switch.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 best shows the overall system. Because the operative device includes a part that moves along the bottom surface, and in addition includes other parts, the entire operative device is called the system and the part that moves across the bottom surface is called the vehicle. The vehicle is generally designated **10.** It is shown in a typical position on the bottom surface of a pool generally designated **11** and having water **11***a* therein. A hose **12** extends from the vehicle to the dry surface around the edge of the pool. The hose is connected to the vehicle with detachable connector **12***a*. This connector, and others as may be desirable as matters of design, may be made as swivel-type connectors to minimize twisting of the hose or torque effects exerted by the hose on elements of the system.

The hose above water level is carried on a hose dispenser or reel **14** in operating addition, the hose **12** is partially or completely unrolled from the dispenser **14,** but in the stored condition, the hose is substantially completely rolled up on it. The section of the hose **12***b* most remote from the vehicle **10,** extends from the dispenser to a tee **15.** This tee has one branch leading to a hose section **12***c* which is connected to the pump suction. Another branch from the tee **15** is blocked with a water proofed grommet **15***a* and permits the egress from the hose of the power line **71.** The power line is provided with a connector **71***a* for connection to a power source.

The structure of the hose **12** and its contents, and of the tee **15** are more fully explained below in connection with FIG. **6,** and also, aspects of the hose structure are further discussed in connection with FIG. **3.** The power source itself is not shown. since the vehicle motors operate at 24 volts, the normal 110 volt A.C. power supply is reduced in voltage by a transformer before connection to power line **71.** The pump is not shown because it is intended that the pump already preexisting in connection with a swimming pool shall be used for this suction purpose. Such pumps are routinely provided to run at normal power line voltages, such as 110 volts (or higher voltages) and have capacities and pumping heads already designed and provided to be suitable for the size and nature of the pool. These pumps are used in the filtration and skimming systems. It is common for such pumps to have alternate inlets positioned at various points around the pool above the water surface where it is intended to connect ordinary pole-type bottom cleaners and hoses to such inlets. Any one of these pre-existing available pump inlets may be connected to hose section **12***c*. It is a common expedient to have a hose section **12***b* come off the inmost end of a hose while on a reel. For example, the inmost end of the hose may be brought into the hub of the reel and out through one end thereof through a swivel connection.

The general mechanical structure of vehicle **10** is best initially described in connection with FIGS. **2** and **3.** The vehicle **10** is provided with an outer covering or sheath **40,** which is shaped to represent a turtle. It is provided with a head portion **40***a*. The head portion **40***a* at least is made flexible so that it will not interfere with the sensing actions of the device.

The vehicle chassis is generally designated **20.** It includes a base portion **21** on the base portion are provided vertically upstanding support panels or risers **21***a*. The outer covering, sheath or shell **40** is mounted for pivotable opening on the panels **21***a*. A hinge pin **22** connects a tab **41** on the cover with the panels **21***a* for the pivotable rotation. A latch tab **47** is provided on the shell at the end opposite from that having the hinge tab **41.** A latch mechanism, generally designated **30** is provided. This includes a screw **32** which is hingedly connected to the latch tab **47** by means of a pivot pin **33.** A rear extension **57** from base **21** is provided, and the latch locking means **34** bears against this extension **57** to selectively hold the shell **40** in firm position on the chassis. The latch lock **34** is a threaded member fitting onto the threaded latch screw **32.**

A pair of scrapers **23** extend forwardly from the vehicle. One of these is mounted on each side of the vehicle and extends outwardly from the longitudinal axis thereof, near the pool bottom surface. They are helpful in scraping and loosening material to be removed from the corners of the pool, which are often rounded, that is, provided with a radius or filet, in both the horizontal and vertical plane, and which are difficult or impossible to directly reach with the suction opening. The scrapers are flexible.

A suction opening **24** is provided in the bottom of the vehicle through the base **21** in close proximity to the pool bottom surface. This suction opening is an inlet to the chamber **49.** A vertical partition, **25,** circular in horizontal view, is provided on the base **21** to partially form the chamber **49.** The circular partition **25** is provided at its upper edge with a resilient sealing member **25***a*.

A basket or strainer **26** is provided inside chamber **49** and resting on base **21** over suction opening **24.** The strainer **26** is provided with a strainer lid **27,** which in turn is provided with a plurality of apertures **27***a* to provide a straining function. This strainer **26** is removable from the vehicle when the shell **40** is unlatched and pivoted open. The strainer **26** is here shown in a simplified form for ease of illustration. It may be a mesh basket. It may be provided with apertures on all its surfaces. It may, for example, be raised above the level of base **21** by means of lugs, and be provided with a mesh or with apertures on its bottom surface as well as its side and top. It is apparent that the addition of more straining area permits more efficient operation and a longer period of time between a required cleaning, and such variations in the basket are a matter of obvious choice or design.

The internal structure of the shell **40** is such that it cooperates in forming the chamber **49** and in retaining the strainer **26**. A strainer lid hold-down tab **46** is provided extending inwardly from the shell **40**. This bears on the lid of the strainer and helps hold it in position. A downwardly extending tab, circular in horizontal view, **45**, extends inwardly from the shell and seats against the sealing member **25**a to help form the chamber **49**. It is seen that chamber **49** is thus isolated from the surrounding water except through the inlet **24**.

A head support block **28** is provided near the front end of the chassis to provide an anchor for support to retain the decorative head **40**a on the vehicle.

A control box **50** is provided above the rear wheel axles. This control box contains the electronic logic and control components of the vehicle. In FIG. 3, the printed circuit board assembly **69** is shown contained within the box **50**.

Motors **51** are provided connected to the rear wheel axles. There are actually four such motors in function, although for each rear drive wheel the two motors associated with each such wheel share certain elements in common and are normally commercially obtained as a unit. The motors are of the type known as gear-motors, and the output shaft runs at a substantially lower speed than the rotor. The output shaft of each of these motors is directly connected to one or the other of the rear drive wheels. The nature of the motors **51** is explained more fully below. The control box **50** and the motor compartments are sealed water-tight to isolate the electronic components and motors from the environment, and the motor compartments are filled with oil.

The vehicle is provided with a left traction belt **56L** and a right traction belt **56R**. Each of these belts runs over a pair of front and rear wheels as shown in FIGS. **2** and **3**. The front wheels are a left front wheel **55L** and a right front wheel **55R**. The rear wheels are a left rear wheel **53L** and a right rear wheel **53R**.

The left front wheel is mounted for rotation on an idler shaft **54L** and the right front wheel is mounted for rotation on an idler shaft **54R**. The left rear wheel is mounted for driven rotation on a drive shaft **52L** and the right rear wheel is mounted for driven rotation on a drive shaft **52R**. Each of these drive shafts is connected to a pair of motors **51**. It is understood that each shaft is connected to what appears to be a single motor unit **51**, and only one shaft extends from each motor unit. As has been explained, each motor unit contains within it functional elements comprising a forward motor and a reverse motor.

The shell **40** is provided with an opening on the top which comprises an outlet **48** from chamber **49**. This outlet **48** is connected to the hose **12** by means of the connector **12**a described in connection with FIG. **1**. It is apparent that the interior of the hose is thus operatively connected to the suction opening **24** through the strainer **26**.

A power line **71** to supply power to the motors and to the logic and control is carried inside the hose **12** in a manner described in more detail below, and enters the body of the vehicle **10** as shown in FIG. **3**. The power line **71** is contained in a gas filled tube **72** in its passage through the hose **12**, and together, the line **71** and tube **72** comprise a flotation-power assembly **70**. Water proof connectors **73** are provided inside the body of the vehicle **10** and at these connectors, the gas filled tube **72** terminates in a water proof seal, and the power line continues into the body to the elements requiring power. Where the power line passes through the circular tab **45**, it is provided with a water proof grommet **74**, to retain the isolation of chamber **49**. The exact path of the leading of the power line **71** to the electrical and electronic components of the vehicle through the body of the vehicle is a matter of design choice to permit opening of the top shell **40** for strainer cleaning without unduly pulling or breaking any wires.

The general structure and general operation of the sensor arms can be best understood in connection with FIG. **2** and to a lesser extent from FIGS. **1** and **3**. There is provided a left sensor arm generally designated as **60L** and a right sensor arm generally designated **60R**. These arms extend outwardly and forwardly from the vehicle **10** at an angle, approximately 45° from the longitudinal axis of the vehicle. The broad concept of such sensors of sensing arms has been known in the prior art, as indicated above. In general, the vehicle, once put in motion, moves in a straight line until one or the other of the sensors **60** touch an obstacle, usually the wall of the pool. Then, depending on which sensor touched first, the vehicle goes through a process to change its direction, and this broad cycle is continued in a self-controlled manner so that the bottom of the pool is cleaned in a effectively random way. It is well known that from a statistical and empirical point of view, such random pattern covering of the surface is satisfactorily effective and efficient. The details of the turns are described in more detail below. Each sensor arm **60** is provided with a pin or shoulder bolt **61** passing through a pin boss or shoulder **61**a on the arm. The structure of the inboard part of the sensor arm **60** is shown in more detail in FIG. **4**, and all that structure is described further below. The outboard or forward end of each arm **60** is provided with an outboard shoulder bolt or pin **66** passing through an outboard pin boss or shoulder bolt **67**c. On the pin **66** is provided a contact wheel **68**. In most cases, it is the contact wheel **68** that makes first contact with an obstacle. Each wheel **68** is free to rotate so as to minimize the possibility of a friction hang-up against the obstacle. Such contact causes a slight horizontal rotation of the arm **60** around its inboard pivot pin or shoulder bolt **61**.

If the vehicle **10** runs into an obstacle having an inwardly extending angle or point, it will be appreciated that the contact could be made with the point coming between the two extending sensors **60**, and the vehicle could stop without either of the sensors being activated. To obviate this problem, sensor arm extensions **67**a are provided on each sensor arm **60**. These extensions **67**a extend toward each other, toward the midline or longitudinal axis of the vehicle in the same horizontal plane as the arms **60**. They are preferably bent as best shown in FIG. **2**. They extend from a point between the ends of the arms **60** as shown. It has been found that this location, which may preferably and conveniently be approximately at the mid-point of the arm **60**, provides a better geometry for reliable sensing and activation of the switches than a location of such extensions at the very forward ends of the arms **60**. Bumpers **67**b are provided at the ends of each extension **67**a. Preferably, these extensions **67**a curve or bend from an initial direction perpendicular to the extension of the arm **60** backwards to a direction more nearly approaching a line transverse to the direction of travel of the vehicle. The head **40***a*, flexible as has been described, bends out of the way when contact is made in its vicinity. As shown in FIG. **3**, the sensors are elevated from and clear of the bottom of the pool.

The inboard structure of the sensor arms **60L** and **60R** and the means by which they activate the sensing switches are best shown in FIG. 4 and FIG. 4*a*. The front of the base **21** is shaped into upwardly extending portions generally designated as a front support block **29**, as shown in FIG. **2**. This support block in general has the function of supporting the front wheel assemblies and also is further differentiated into separate elements as best shown in FIG. **4**. One support portion **29***b* forms part of the circular partition **25**, and also serves as part of the overall sensing means. The other support portion **29a** provides a support for the pivot of the arm **60**. The shoulder bolt **61** rides in a bearing in support portion **29***a*. Inboard of shoulder bolt **61**, the arm **60** is extended to form a cam **64**. An arm return spring **65** is provided to return the arm **60** to its neutral position after contact is removed. The spring **65** is supported between a spring pin **65***a* extending from the cam **64**, and a fixed position spring pin **65***b* extending from the support portion **29***b*.

As shown in FIG. **4**, the upper surface of cam **64** is an upwardly facing concave surface. A cam follower or switch operator **63** extends downwardly onto the face of cam **64**. In the neutral position of the arm **60**, the follower **63** rests at the bottom of the concave upper surface of the cam. The follower **63** actuates switch S2. The structure shown in FIG. **4** for arm **60L** is duplicated for arm **60R**, which operates switch S1. The switch is mounted on a switch mount **62**. The mount **62** is provided with downwardly depending extensions **62***a* which form pivot stops or limits to limit the maximum swing of the arm **60** from its neutral position. One of these pivot stops **62***a* is provided on each side of the cam **64** to limit its horizontal travel in either direction. One of the pivot stops **62***a* is shown in FIG. **4**. In FIG. **2**, it is understood that one of these pivot stops is provided on each side of the switch mount **62**. It is apparent that when an arm **60** makes contact with an obstacle, the follower **63** rises and actuates the switch S2, and that when the contact with the obstacle is broken, the follower **63** drops and the switch is no longer pressed.

A preferred form of a cam follower and its associated structure is illustrated in FIG. 4*a*. This form is adapted to operate a more commonly available and economically obtainable type of switch S2 which permits a limited degree of travel and has a limited resilient bias to insure reliable return downwards of a cam follower. This preferred form of cam follower is generally designated **83**. The switch mount **62** is provided with a downwardly extending boss **62***b*. The follower, switch operator or plunger **83** is provided with laterally extending pins **85**. A return spring **84** is positioned around the follower **83** between the boss **82***b* and the pins **85**. This spring **84** provides the main strong thrust for holding the follower **83** against the cam **64** and insuring that it returns downwardly when the arm **60** returns to its neutral position after a contact.

Provision is made so that there is no damage to the switch or to any other part of the structure by reason of the fact that the mechanical travel of the switch is smaller than the overall travel of the follower **83** pivot for example, an hermetically sealed switch **S2** of an economically desirable type may have a travel on the order of 0.050 inches, whereas it is not easily practical to provide such a limited scope of travel under the operating conditions in the remainder of the sensing structure. For this purpose, a lost motion or over travel means is provided. This means comprises a secondary plunger **86** positioned for axial movement within the recess **83***a*. The secondary plunger is biased upwardly by an overtravel spring **87**. The switch actuator **90** bears against the top of the secondary plunger **86**, and the compound plunger assembly moves vertically within the hole **62***c*. It is apparent that as plunger **83** moves upward, the spring **87** is compressed and when its force is great enough to overcome the resistence of the actuator **90**, the switch S2 is actuated. Thereafter, additional upward travel of plunger **83** results in additional harmless compression of spring **87**.

One advantage of the sensing arm-switch structure in this invention is that the simple reliable switch is reliably actuated regardless of the direction in which the arm pivots upon contact with an obstacle.

The structure of the tee **15**, described above generally in connection with FIG. **1**, is understood in more detail in connection with FIG. **6**. The hose section **12***b* contains a flotation-power assembly **70**. This assembly comprises a sealed, water tight, gas filled tube **72**. The power line **71** is contained within it.

The hose **12** containing power line **71**, when full of water, would tend to sink and produce drag on the vehicle and some difficulty in handling because of the weight of the wire **71**, even though the hose along would float. By providing the gas filled tube **72** inside the hose **12**, a number of functions are performed. One of these is that the hose-wire assembly then tends to float. This insures that the hose is off the bottom and out of the way of the vehicle and also reduces other possible interference with the operation of the vehicle. It makes the hose **12** more easily moveable, both by the vehicle and by an operator who may wish to shift it. Another function is that it provides a dry environment for the power line. Other functions are that it provides additional insulation for the power line and some additional protection against chafing of the power line. The gas in the tube is normally simply entrapped air. The relative dimensions of the hose, power line, and tube are not critical. The hose may be of polyethylene and have an I.D. of 1½ inches. The tube **72** may be of vinyl with an O.D. of three-eighths inch and a wall thickness of approximately one thirty-second inch. Any air at all in the tube provides some benefit, and increased amounts of air provide more of these benefits with the limitation that as the tube **72** gets larger, the effective cross-sectional diameter of the hose **12** for the passage of water and debris is reduced. Another limitation is that the size of the air tube should not be so great that there is a appreciable lifting effect tending to hold the vehicle off the bottom or to recude its traction. Less preferably tube **72** may be filled with non-gaseous flexible material instead of air, as foamed insolated-cell flexible plastic, or the tube and air may be replaced by a sheath of such material. The requirement is that the weight of the power line **71** be offset by a surround having a density less than that of water.

At the dry or land end, at the tee **15**, as shown in FIG. **6**, the tube **72** terminates in a sealed collar **70***a* around the power line **71**. The power line passes through one of the branches of the tee through a hole in the water proof grommet **15**a. The other branch of the tee leads to the hose section **12**c connected to the pump, as has been described. The tube **72** may be terminated and sealed at the other end, within the body of the vehicle, in the same way.

The switches in the sensing means are normally off. They are preferably of the moistureproof, non-snap type, with an integral push button or actuator. Preferably, they are of a low-bounce type, and may have an operating force of approximately three pounds.

The motors in the prefered embodiment are 24 volts A.C. motors. Each motor may have a rating of 60 watts. Such motors are available for example from the Molon Company. The motor unit includes one shaft. This shaft has on it two electrically isolated rotors, spaced along the shaft. There are two electrically isolated armatures, one associated with each of the rotors. The armatures are reverse wound. Thus, when one armature is energized, the shaft rotates in a forward direction, and when the other armature is energized, the shaft reverses. Thus, though this is a single housed unit, sharing certain elements, it is in function two separate motors, operating in reverse directions. It is of the shaded pole type, and has an integral gear reducer so that the output at the shaft connected to the drive wheel of the vehicle may be between approximately 18 and 25 RPM. An advantage of providing this type of reversing is that there is no necessity to provide capacitors which would be large at the low voltage used and which tend to discharge at twice the operating voltage. Thus, the under water electrical system is maintained at a safe low voltage and the reliability of the equipment is increased.

The overall logic and control is best broadly understood in connection with FIG. **5**a. The two switches, which correspond with switch **S1** and **S2** in the drawings, are connected through a switch interface **82** to a timer and logic section **93**, which acts on a motor control section **94**. The motor control in turn operates the four functionally independent motors all generally designated **51**, and individually identified as left front LF, right front RF, left rear LR, and right rear RR.

The pump to handle the suction will vary in its size and other parameters depending on the pre-existing filtration and skimming equipment at the pool, but its motor may be of the order of magnitude of one horsepower and operates on full available line voltage.

FIG. **5b** is a schematic drawing of the circuits involved to carry out the functions of the block diagram of FIG. **5**a. The four functionally independent motors **51**, individually identified LF, RF, LR, and RR as described above, are found also in FIG. **5**b. Elements **S1** and **S2** in FIG. **5**b correspond to switch **1** and switch **2** respectively in FIG. **5**a.

Swtich **1** is part of the left sensing means and is operated by the sensing arm **60**L. Switch **2** is part of the right sensing means and is operated by the sensing arm **60**R.

The program and logic of the electronic system and of the vehicle may be described as a seven step program. Some important aspects or characteristics of the program are as follows. The vehicle turns in a direction away from the contacted sensor. Between each step involving movement there is a pause or halt. This pause or halt time prevents undue strain or damage to mechanical parts due to sudden reversals and also prevents damage to or overheating of motors because of current surges due to sudden reversals. A very important aspect of the program is that after a contact is made, before a turning motion starts, the vehicle backs up in a straight line for a short distance. Then, the turn is made, and then the forward motion is resumed. The existence of the back-up step contributes in an important way to minimizing the possibility of the vehicle being trapped against or between an obstacle or obstacles and going into a pattern of repeated coverage of a small area of the bottom in the vicinity of the obstacle or obstacles. If there is no back-up, there is a higher possibility that the vehicle will not be able to free itself from an obstacle to continue its random coverage of the bottom and that a rigid sensor arm may be broken during a turn. If both sensors **60L** and **60R** are struck in succession before a complete turn cycle has been effected, the system locks out the sensing means so that the second strike is ignored. If both sensors are struck simultaneously, the vehicle will not be stalmated.

The seven step program or cycle when switch **1** is actuated is as set forth in the following table:

1.	LF	RF
2.	Halt	T
3.	LR	RR
4.	Halt	T_2
5.	LF	RR
6.	Halt	T_3
7.	LF	RF

In the table, the duration of time of the three successive half or pause periods are respectively identified as T, T_2, and T_3. LF means left forward, RF means right forward, LR means left reverse, and RR means right reverse.

If switch **2** is actuated, the program as set forth above is the same except that in step 5, the L and R are reversed. If one switch is actuated, the system sequences through its cycle with the other switch locked out.

Steps 7 and 1 are the same, and represent the normal forward motion of the vehicle.

The above program for the sequence or cycling of a random motion device with contact sensors is in itself an improvement over previously known methods and mechines.

In FIG. **5**b, in addition to the identification of elements given above, in general the coding of elements in the schematic is as follows: R, resistor; C, capacitor; Q, transistor, some of which are unijunction transistors (although Q12 – Q15 are triacs); M, motor; D, diode; RL, relay; F.F., bistable multivibrator (flip-flop). The schematic has been divided into sections by dashed lines, approximately divided into functional sections, including the blocks in FIG. **5**a.

The power supply section is supplied with 24 volts A.C. from the transformer as has been described. The 24 volts A.C. is also supplied directly to the motors to operate them. Resistor **R28**, diode **D32**, **R28** and capacitor **C8** comprise a half wave rectifier. Voltage to power the relays is provided from the junction between **R28** and **D32**. This is about 14–20 volts DC. The voltage required for the logic circuit is 5 volts, and this is provided by the remainder of the power supply, after **R28** and **D33**. **D33** is a zener diode which regulates the voltage.

In the motor control, for the four motors LF, RF, LR and RR respectively, **R21**, **R23**, **R25**, and **R27**, and **C4**, **C5**, **C6**, and **C7**, are part of the motor starter circuits for the respective motors with which they are associated in the schematic. Q12, Q13, Q14, and Q15 are triacs, which act as AC switches. They each operate on the motor with which they are associated in the schematic. R20, R22, R24, and R26 are limiting resistors for the respective triacs with which they are associated.

The legend RL denotes a reed relay, and there is one of these relays for each motor. In the schematic, one side of the relays are each denoted respectively RLk, RL2, RL3 and RL4, and the other side of the relays are each denoted respectively RL1'. RL2', RL3' and RL4'. A resistor R51 is provided between the power supply and the relays.

In the bistable multivibrators or flip-flops, the outputs are identified as terminals **0** and **1**, reset is R, set is S, and clock is C. These are conventional electronic circuit elements.

When power is applied to the vehicle **10**, both FF1 and FF2 have their terminals **0** high which prevents the diodes D1 and D2 from conducting. This state permits the pull-up resistor R1 acting through the isolation diodes D3 and D4 to forward bias the relay driver transistors Q8 and Q9 which turn on to ground, and which in turn energize relays RL1 and R12. These in turn turn on triacs Q12 and Q13, which start the motors LF and RF. This puts the vehicle **10** in its normal forward mode. This mode continues indefinately if no switch S1 or S2 is actuated.

In that portion of the description immediately following, the functions are described in terms of the left sense switch S1 being actuated, with the corresponding effect when right switch S2 is actuated being inserted in parenthesis.

When the left sense switch S1 (or right sense switch S2) is closed, terminal **0** of FF1 (or FF2) goes low, causing diode D1 (or D2) to conduct. This stops the forward biasing of Q8 and Q9, thus opening relays RL1 and RL2, which turn off triacs Q12 and Q13, causing the motors LF and RF to stop. At the same time, terminal **1** of FF1 (or FF2) goes high causing diodes D16 and D17 to conduct which through R4 and diodes D14 and D15 forward bias Q10 and Q11. The relays RL3 and RL4 close and Q14 and Q15 turn on starting the motors LR and RR.

At the same time, when the switch S1 closes, the low state of terminal **0** of FF1 (or FF2, in the case of closing of switch S2) shuts off the forward bias, which is supplied by R5, of master timer gate Q1 and reset transistor Q2. The lock-out of timer multivibrator FF3 and timing capacitor C1 ceases and C1 begins charging through timing resistor R7, R9 and D18. When the voltage across C1 rises to a critical point, the unijunction transistor Q3 fires, causing pulse generator Q4 to create a negative pulse which changes the state of FF3. Terminal **0** of FF3 goes low, causing D13 to conduct, turning off Q10 and Q11. Relays RL3 and RL4 then open, causing triacs Q14 and Q15 to turn off, which cause motors LR and RR to stop. Terminal **1** of FF3 goes high, and D5 (or D9 if S2 is closed) and D6 (or D10) cease conducting, forward biasing the transistors Q8 and Q11 (Q9 and Q10) through R2 (or R3). Relays RL1 and RL4 (or RL2 and RL3) close and triacs Q12 and Q15 (or Q13 and Q14) turn on, starting motors LR and RR (or motors RF and LR). The unijunction transistor Q3 again fires, changing the state of FF3 after a time period determined by C1 and R8 and R9. Terminal **1** of FF3 goes low, causing D6 and D10 to conduct, turning off Q8 and Q11 (or Q9 and Q10). This causes all motors operating on the alternate mode to stop. At the same time, pulse generator Q5 resets all the multivibrators to their original states, and the motors LF and RF again run. The pause or half interval timer permits the motors to come to a complete halt before reversal. This timer operates at the start of each change of state. When either sense switch S1 or S2 is closed, FF4 changes state permitting timing capacitor C3 to start charging, and, as in the other time, when the critical point is reached, causing the unijunction Q6 to fire and reset FF4. At the start of the timing cycle, terminal **0** goes high and releases the clamp diode D20 permitting charging of timing capacitor C3. The terminal **1** is low, causing forward bias to be removed (for the timing period) from Q8, Q9, Q10, and Q11, thus turning off all relays and triacs, and thus turning off all motors. The initial starting pulse comes from the sense switches, when closed, through the decoupling diodes D21 and D11. Remaining pulses come from the master timer through decoupling diode D23.

Certain aspects of the operation of the circuit shown in schematic FIG. 5*b* can be further described in additional detail. When switch S1 is actuated and closed, a negative pulse sets FF1 terminal **0** low and terminal **1** high. The pulse also goes through D22 to the reset R of FF4. When FF4 resets, terminal **1** of FF4 goes low and shuts off all transistors Q8, Q9, Q10, and Q11 in the motor control. Then diodes D24, D25, D26 and D27 conduct and therefore all the transistors Q8-Q11 are turned off and clamped. Therefore, all the motors stop.

When FF1 terminal **0** goes low, it resets FF2 at reset R. Therefore, switch S2 cannot set FF2 at set S, because it is clamped or locked out.

Note that most of the description relates to the function following an actuation of switch S1. When switch S2 is actuated instead, there is an obvious symetrical reversal in the function as is clear from the schematic.

Before an initial switch contact, Q1 and Q2 are both conducting. Q1 keeps C1 from charging and Q2 keeps FF3 in reset. This inhibits the timing circuit and prevents it from interfering with the forward operation of the vehicle.

After S1 is closed, neither Q1, Q2, Q8 or Q9 conduct since D1 and D2 conduct and both sides are low. As explained, after closing of S1, FF4 is reset and thus all the motors are stopped.

The timer is now discussed. As Q2 turns off when S1 is closed, it releases reset R on FF3 so that terminal **0** goes high.

When Q1 turns off, it releases C1 so that the capacitor C1 can now charge. This charging times the first halt or pause step. It changes through D18, R7 and R9 because terminal **1** of FF3 is now high.

When the C1 voltage reaches the critical level for that capacitor, the unijunction Q3 fires (conducts). When Q3 conducts, Q4 also conducts. The pulse to trigger Q4 is developed from Q3. When Q4 conducts, the clock input C of FF3 goes low, so that FF3 flops or changes state.

When switch S1 is closed, flip-flops FF1 and FF4 reset, and capacitor C1 and C3 both start charge. C3 charges fully before C1, so the unijunction Q6 fires first. It turns on Q7, and permits the capacitor to discharge. The pulse from Q7 clocks FF4 at clock terminal C. Since Q7 conducts, the clock C terminal goes low. Before this pulse, terminal **0** of FF4 was high and terminal 1 was low. So, after the pulse, the FF4 terminal 0 goes low and the flip-flop FF4 clocks to the set state. C3 cannot recharge because FF4 terminal 0 has gone low. Terminal 1 of FF4 has now gone high, so that all the control transistors are unclamped. Therefore, two of the motors are now free to run. These are the reverse motors RF and RR.

The reverse motors are actuated as soon as switch S1 is closed, but because of the FF4 clamp, the actuation of the path is of no effect. When C3 charges, FF4 changes state, the control transistors are unclamped, and the reverse mode is in operation.

Electrical reverse motor path is **Q10, R18, D14, R4** (and through **D16,** if S1 is closed). If S2 is closed, the path is through **D17** instead of **D16,** and the path is through **Q11, R19, D15,** and **R44,** and is otherwise the same.

So, the charging time of capacitor of C3 determines the length of the first stop, pause, or halt. Resistor **R13** sets the length of this halt time by adjusting the charging time of C3. C3 is shorted through **D20** to the low terminal **0** of **FF4,** so C3 does not recharge.

Then, capacitor C1 starts charging, and when fully charged, it changes the state of FF3, through **Q3** and **Q4,** and also resets FF4 through **D23.** When C1 is charged, FF3 sets terminal **0** low and terminal **1** high. FF4 is reset with terminal **0** high and terminal **1** low. When FF4 terminal **1** goes low, it clamps the control transistors. When FF4 terminal **0** goes high, C3 can start to charge again. C1 starts to recharge through **D19** and **R8.** This provides the halt or pause after the vehicle reverse step in the cycle.

The next step is the turn mode. FF3 terminal **0** low and terminal **1** high set permits the setting of FF1 to have the turn mode go on. Through D1, Q9 turns on through **D11. Q10** turns on through **D12,** so, in the turn mode, relay RL2, operating through control transistor **Q9,** permits motor RF to operate, and relay RL3, operating through control transistor **Q10,** permits motor LR to operate. During the turn mode, C1 is charging and C3 has discharged. Then, C1 fully charges, setting the time period for the turn mode, and clocks FF4 to the reset state, and FF3 to set terminal **0** low. When FF4 is reset, C3 restarts to charge. When FF3 terminal **0** is low, Q5 pulses and resets **FF1** and **FF2.** The system is now back to its initial state with the forward motors in operation.

It is understood that the diodes **D3-D8,** and **D11-15** are isolation diodes. And that diodes **D28–D31** form a similar function in connection with the relays. It is noted that resistors **R7, R8,** and **R13** are shown as variable resistors in the schematic. They are shown this way because setting of these resistors determines the various timing rates, but in ordinary commercial forms of the invention, once these resistance values are chosen to select pre-determined desirable time periods, it is not necessary to provide them in the unit as variable resistors. It is understood that an operable circuit is disclosed in the schematic itself and the foregoing description helps to explain the operation of this circuit, and that since most of the description relates to the circumstances under which switch S1 is closed, certain obvious other paths and elements having the same logic but controlling different motors are involved if switch S2 is closed first.

In general, the element generally designated **10** in FIG. **1** is called the vehicle, and the vehicle in addition to the other elements, including for example the hose, pump, etc, is called the system. The motors, wheels, and traction belts are called the drive means. The arms **60** and their associated structure including the switches are called the sensing means. The elements shown in FIG. 5*b*, excluding the motors and switches, are called the logic and control means.

The invention as described is of the preferred embodiment and the elements of the invention combine to produce advantageous results. However, it is possible within the scope of this invention to modify certain elements of the combination and still retain inventive advantages. For example, the pump could be provided on the vehicle itself, with the sacrifice of certain advantages, as has been explained. It would be possible instead of using four functionally independent motors, to use two motors and make them reversible motors, with the disadvantages that have been previously explained. It is possible, instead of using the rubber traction belts **56,** to couple the front wheels to the drive wheels with chains or gears, although such a structure is not preferred and does not have the full advantages of the present structure. It would be possible to provide the vehicle with three wheels instead of four, substituting a single wheel for the two front wheels, although this would not be preferable. It would be possible to provide a motor on each of the four wheels, with one reverse and one forward on each side.

It would be possible to use an electric brake or clutch on the motors instead of a halt or pause. This would be a more expensive expedient, but would speed up the cycle. It would be possible to provide sensing arms longer than those presently illustrated and to make them flexible. In such a structure, the cycle could lead to an immediate turn rather than a back-up step, with the compliance of the flexible arm permitting the immediate turn without breaking the arm or forcing the vehicle to slip and the extra length of the arm reducing the changes of the vehicle being stalmated. Such a structure is not considered preferable.

It is possible and desirable to provide a switch to prevent operation of the vehicle drive motors out of water, to avoid overheating of the motors or the triacs. This means may be a bouyancy switch, such as a ping-pong ball floating in a retaining cage, or a pressure-actuator or suction-actuated switch.

The logic can be performed by means of relays or by a combination of relays and rotary switches. The timing may be performed by motor driven adjustable cams or by feeding screws, or by thermal relays. It is understood that such non-electronic, means which in some cases include additional motors, mechanically moving parts, and parts subject to unreliability under the desired service, are not considered preferable. Fluidic logic, using an hydraulic system could be used for the logic. It could use the pump suction for power and utilize valves instead of switches as part of the sensing means. Fluid motors driven by the pump might be used for the primary drive of the vehicle. It is understood that such a structure is not fully disclosed herein, but for the purpose of certain aspects of the invention, particularly the programming, and the concept of the separate pump and, the hose system, for example, such fluidic logic is considered an equivalent.

Referring to FIG. **4,** instead of a cam system, all mechanical contact could be avoided, by using a magnet and a reed switch, or by using photo cells. FIG. **7** shows a type of connection between a sensor arm **60L'** and a switch, in which the coaction is magnetic. The arm, generally designated **60L'** is provided with a boss **61***a'* and pivots around a pin **61.** A vertical extension **100** of the arm is provided near one end thereof. This extension carries a permanent magnet **101** which is exposed at or near the end vertical surface of the extension **100.**

A magnetic reed switch **103** is provided in the support portion **29***a'*, with its magnetically sensitive surface facing toward the magnet **101.** The arm is spring biassed to a neutral position in the same manner as set forth in connection with the embodiment of FIG. **4.** When the arm is in its neutral position, the magnet is centered over the switch and the switch remains open. When the arm pivots, and the magnet therefore moves from a central position with respect to the switch, in either direction, the switch closes. The switch remains closed until the magnet returns to a central position, and the logic circuit responds to this signal in the same manner as has been described above.

The sensitivity of this switch is a function of the gap between the magnet and the switch, the strength of the magnet, and the sensitivity characteristics of the switch, and the choice of a desirable sensitivity as a matter of obvious design. For example, the magnets are commercially available in one-fourth inch diameter, and have lengths for example of 1 inch, ⅞ inch, ¾ inch, with the longer the length, the greater the flux. It has been found that magnets of this diameter with lengths of ⅞ inch or ¾ inch, gapped approximately ⅛ inch from a magnetic reed switch, are satisfactory. Suitable reed switches comprise a glass tube containing two arms which are magnetically moveable. Such switches are available for example from Hathaway Industries, Inc., General Reed, and C.P. Clare Co.

This type of switch actuation is advantageous in that it eliminates mechanical connection to operate the switch and thus reduces the possibility of failure of the system because of corrosion or fouling by debris. This type of switch actuation is in some senses a preferable embodiment.

The strainer, as shown in FIG. **3,** can be made disposable, instead of cleanable. It may be provided outside the vehicle. If the pump is to be mounted on the vehicle, a filter can be included. It is noted that in the preferred embodiment illustrated, the vehicle includes a strainer, not a filter, since any filtration takes place in connection with the pre-existing pump which is part of the pool facility.

The reel, as shown in FIG. **1,** can be made a portable unit, with compartments or other provision to carry the vehicle, and can carry a transformer and main switch. The size of the strainer can be expanded to cope with conditions involving many leaves for example. One possibility is the provision of a over size strainer system on the back of the unit instead of the strainer contained within the interior of the vehicle.

electrical connector swivels may be used where required, just as the hose swivels, as is obvious.

A transverse brush, stationary with respect to the vehicle, may be mounted on the vehicle just to the rear of the inlet **24,** to loosen debris and kept it swept into the hose served by the suction.

The system can be used for cleaning industrial tanks as well as swimming pools.

It may sometimes be desirable to operate the vehicle by direct remote control, rather than to permit it to move randomly. For example, such controlled operation may be useful in certain areas of larger tanks. This control may be by wire or even by radio or other wireless means. Such remote control operates the switches **S1** and **S2.** Since such control would typically be exerted only part of the time on the random motion vehicle otherwise as claimed and described, it is understood that the claims include the concept.

It is understood that the foregoing mentioned modifications are not intended to be exclusive or to limit the scope of the claims, but are intended to suggest certain modification from the preferred embodiment. It is not maintained that each of these modifications would necessarily result in an equivalent structure to that of the preferred embodiment.

I claim:

1. A random motion vehicle having a forward end and normally adapted to move in a straight line with said forward end leading across a horizontal surface, to sense an obstacle, to turn away from said obstacle, and to continue to move in a changed direction with said forward end leading, said vehicle comprising,

a base, said base supporting the following means,

only a left side forward end obstacle contact sensing means and a right side forward end obstacle contact sensing means,

a left side independent drive means and a right side independent means, each said drive means including at least one motor and at least one wheel, each said wheel being rotatable only in a plane parallel to the direction of motion of said vehicle and driving a horizontal surface-contacting traction belt,

a logic and control means operatively connected to said drive means and said sensing means to turn said vehicle to change said direction of motion, by sensing an obstacle contact sensing signal from one of said sensing means causing said logic and control means to initiate a programmed cycle of instruction signals to said drive means, said cycle being; left and right drive means pause, left and right drive means reverse; left and right drive means pause; one of said drive means drive reverse and the other of said drive means drive forward, left and right drive means pause; left and right drive means resume normal forward drive.

2. A method of controlling a random motion vehicle having a first and second side, and a front and back, so that normal operation is in a straight line with said front leading and so that obstacles are turned from without a repeated pattern, a sensing means on each of said sides, and independent drive means on each of said sides, each of said drive means being capable of forward or reverse motion, comprising the steps of normally operating both drive means forward to provide straight line vehicle motion in a first direction, and when an obstacle is contacted by said sensing means on said first side, automatically turning said vehicle from said obstacle by operating both said drive means in reverse motion, then operating said drive means on said first side in forward motion and said drive means on said second side in reverse motion until said turn is completed, and then resuming normal straight line forward motion of said vehicle in a second direction by operating both said drive means forward.

3. A method as set forth in claim **2** wherein after said contact is made by said sensing means on said first side, said sensing means on said second side is inoperative until all steps have been completed.

4. A method as set forth in claim **2** wherein between each of the recited steps, there is provided a period of pause during which both drive means are inoperative.

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