Aug. 31, 1965 H. A. GABERSON ETAL 3,203,500

AREA COVERING DEVICES

Filed Oct. 22, 1962 7 Sheets-Sheet 1

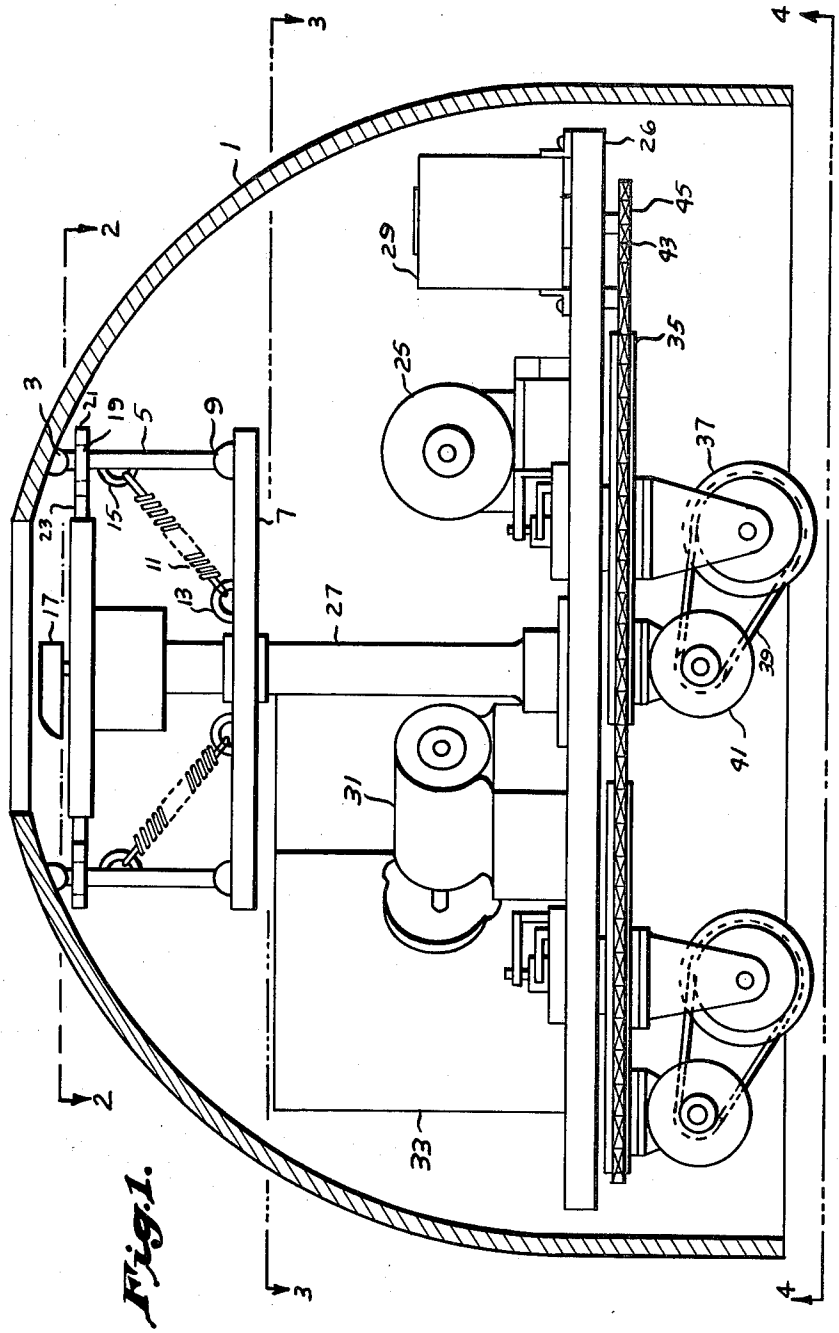
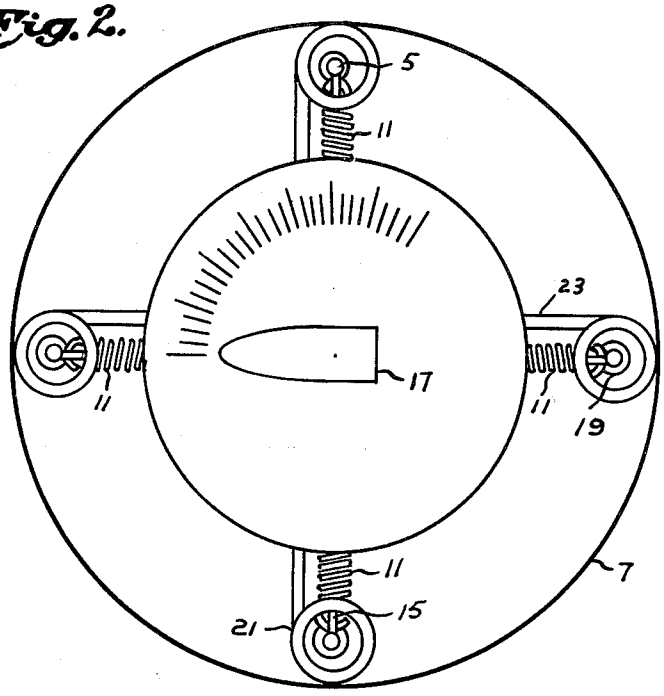


Fig. 1.

Fig. 2.


5
11
23
17
11
11
19
7
11
21
15

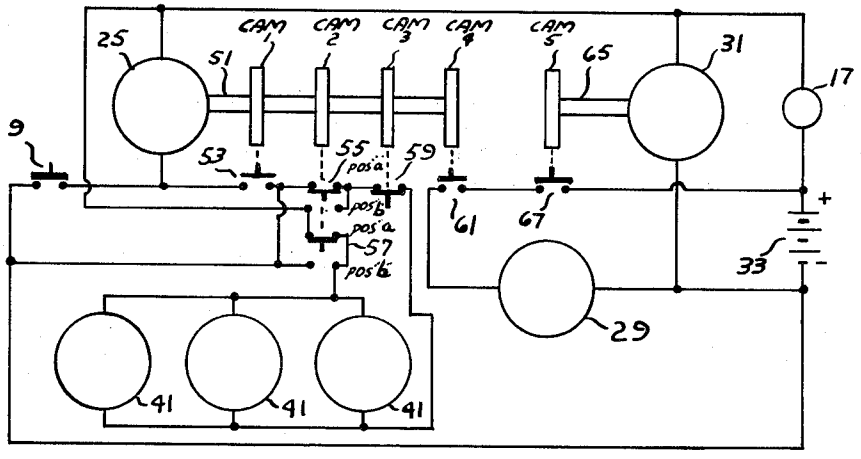

25
CAM 1
CAM 2
CAM 3
CAM 4
CAM 5
51
65
31
17
9
53
55
pos a
59
pos b
pos a
57
pos b
61
67
+
33
-
29
41
41
41

Fig. 8

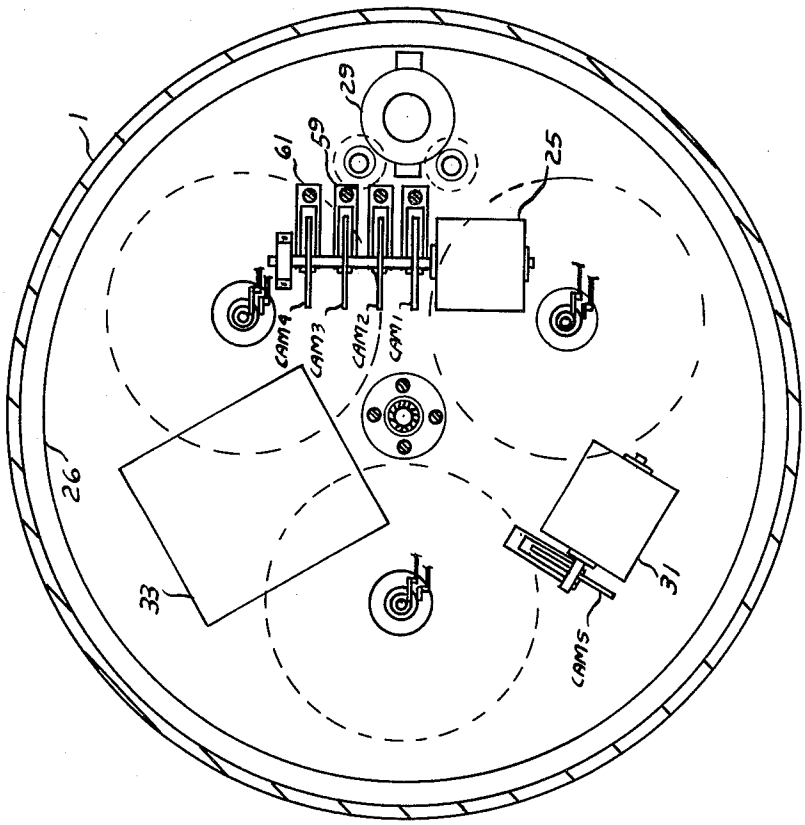


Fig. 3.

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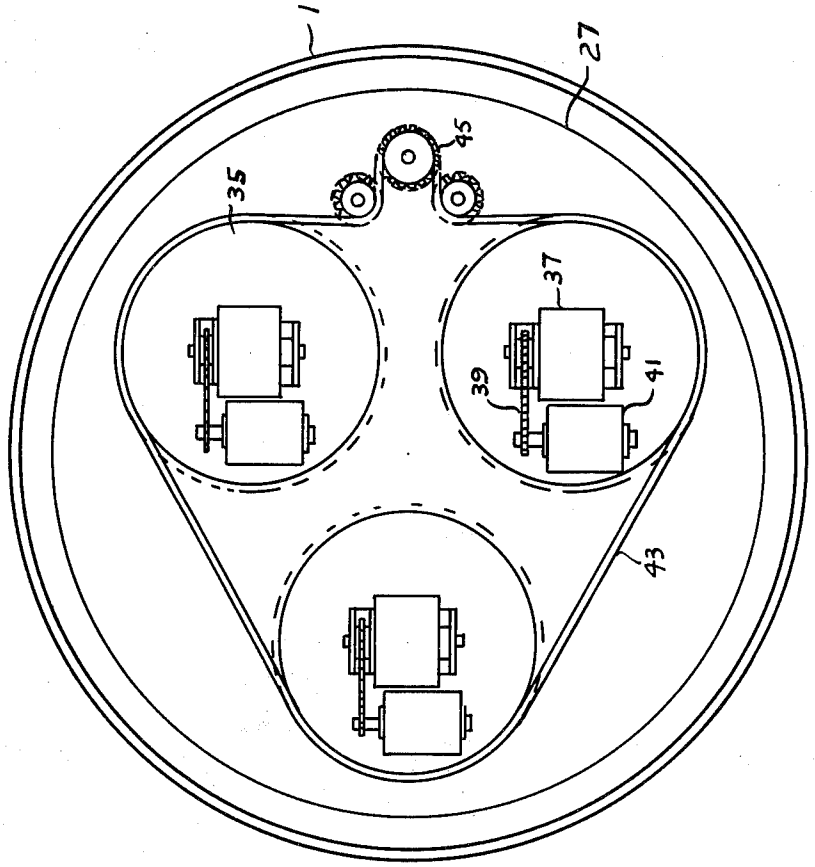


Fig. 4.

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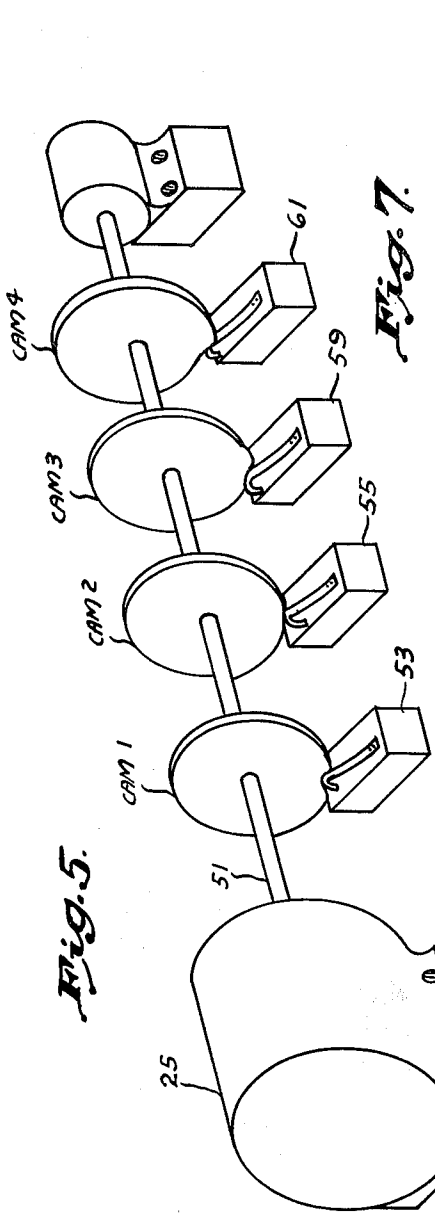


Fig. 5.

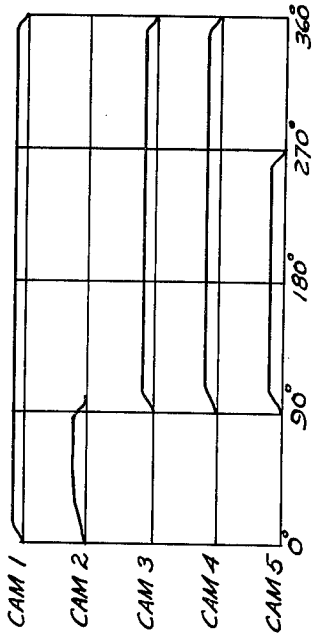


Fig. 7.

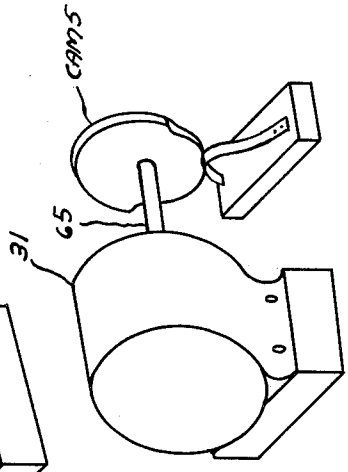


Fig. 6.

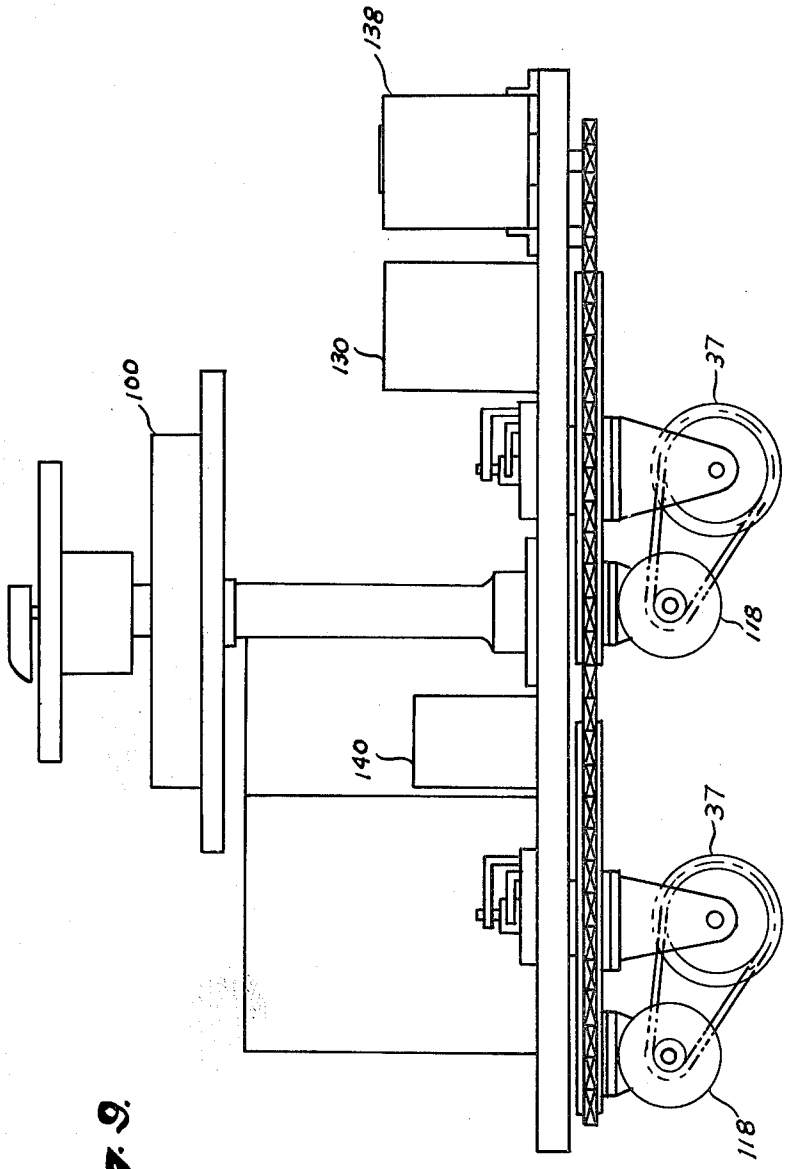


Fig. 9.

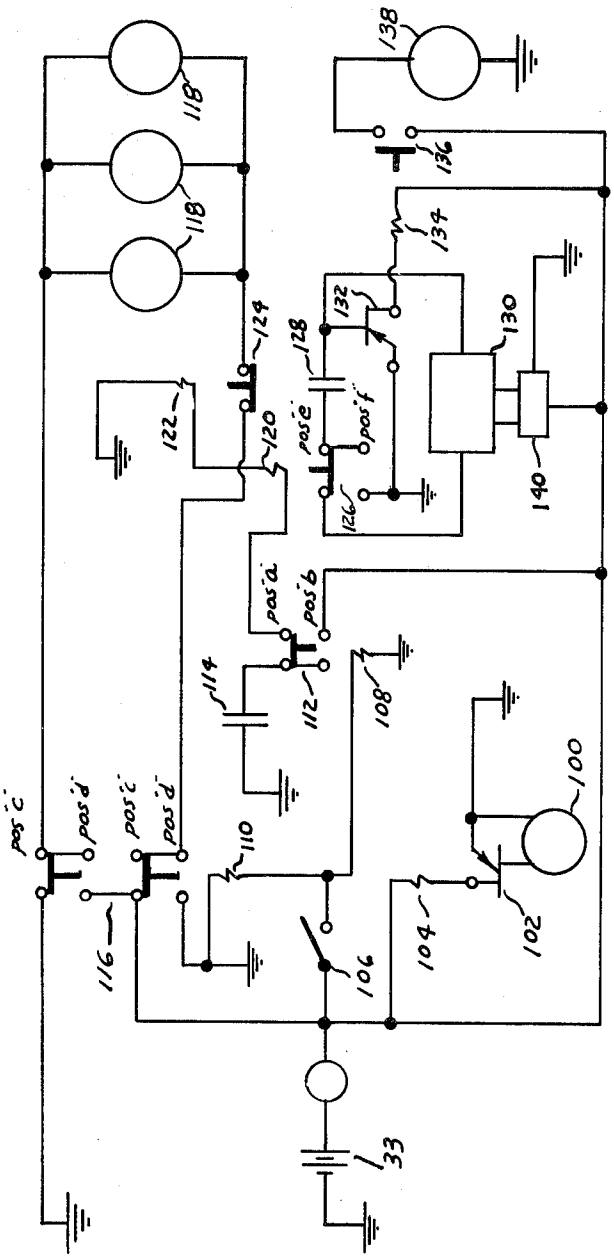

138
118
118
136
134
132
130
128
124
pos e
pos f
122
120
126
140
pos a
pos b
114
112
108
pos c
pos d
pos c
pos d
110
100
116
106
104
102
133

Fig. 10.

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Patented Aug. 31, 1965

3,203,500

AREA COVERING DEVICES

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Filed Oct. 22, 1962, Ser. No. 231,973
3 Claims. (Cl. 180—79.1)

This invention relates to area covering devices and in particular to novel, self-propelled, self-directing devices capable of substantailly completely traversing a predetermined area.

Heretofore, devices such as tractors, vacuum cleaners, runway sweepers, or lawn mowers that were intended to completely traverse a prescribed area, derived their guidance, directly or indirectly, either from external sources or from previously programmed guidance that was internally stored. Thus, for example, when it was desired that a tractor completely traverse or cover a given area, it was generally necessary that it be guided directly or indirectly by a human being or by some automatic or semi-automatic devices(s) of the type disclosed in U.S. 2,509,914; 2,513,868; or 1,696,352.

The area covering devices of the present invention, however, without any programming or stored guidance and while operating free of any external signal, are capable of traversing a given predetermined area substantially completely.

Accordingly, it is a principal object of the present invention to provide an improved device for substantially completely traversing a predetermined area.

Another object of the present invention is to provide a device which is capable of, freely and independently, and without the aid of either external guidance or internal programming of any kind, substantially completely traversing a predetermined area.

Another object of this invention is to provide a device which will while traversing a predetermined or prescribed area without external signals or internal programming, stay continuously within the bounds of said area.

Still another object of the present invention is to provide a device which will randomly but substantially completely traverse a predetermined area.

Still another object of this invention is to provide a device which will without external aid of any kind perceive barriers and continuously avoid them.

Still another object of this invention is to provide a device which will, without any external aid of any kind, continuously traverse a predetermined area.

Other objects of this invention will in part be obvious and will in part appear hereinafter.

The area covering devices of the present invention harness and exploit the surprisingly high rate of efficiency exhibited by a body moving continuously, but substantially randomly, in traversing substantially completely a given area. More precisely, an area covering device of the present invention upon being actuated and placed within a prescribed, predetermined area, as will be explained in more detail hereinafter, moves in a relatively straight line course until a "barrier" is percepted, whereupon the device, automatically, but substantially randomly, alters its direction of travel from 0° to 360°; then the device again proceeds in a relatively straight line course until a "barrier" is perceived whereupon the cycle is repeated, and so on.

While the relative efficiency of the randomly directed area covering devices of the present invention has been demonstrated, said relative efficiency can be explained methematically as follows:

Assumptions:

(1) It is assumed that the size of the area covering device is small relative to the total area to be traversed

(i.e., that the size of the device is less than about .1% of the total area to be covered).

(2) It is assumed that since said device moves randomly or substantially randomly, the probability of said device, traversing an area already traversed at any given time, is equal to the ratio of the traversed area to total area.

Both these assumptions clearly are valid.

The factors utilized in the mathematical determination are as follows:

A=Total area;
C=Ratio of area traversed to total area;
T=Time;
V=Velocity of device;
W=Width of device;
R=Rate at which untraversed area is traversed;
P=Probability of traversing a previously non-traversed area;

$$\Phi=\frac{\text{Actual time for total traversal to a given value of C}}{\text{Minimum possible time for total traversal}}$$

Statistically, or on the average, the rate at which untraversed area is traversed can be expressed as follows:

(1) $$R=WVP$$

Therefore the non-traversed area traversed from time equals zero until time equals T, can be expressed as

(2) $$\int_0^T R\,dt$$

The probability that the device is traversing an area not previously traversed is thus equal to the ratio of the non-traversed area to the total area; by using (2) and the above definitions

(3) $$P=\frac{A-\int_0^T R\,dt}{A}$$

By substituting the value of R from (1) and simplifying one obtains

(4) $$P=1-\frac{1}{A}\int_0^T WVP\,dt$$

Differentiating (4) with respect to time

(5) $$\frac{dP}{dT}=-\frac{WVP}{A}$$

Rearranging

(6) $$\frac{dP}{P}=-\frac{WV}{A}dT$$

Integrating one obtains

(7) $$\ln P=-\frac{WV}{A}T+\text{const.}$$

The constant can be evaluated by noting that when

$T=0$, $P=1$; therefore the constant=0

Substituting these values into the above equation shows that the constant must be equal to zero. Hence

(8) $$\ln P=-\frac{VWT}{A}$$

From (3) and noting the definition of C, the following relation becomes clear:

(9) $$P=1-C$$

Therefore from (8) and (9) the

$$\ln(1-C)=-\frac{VWT}{A}$$

Upon rearrangement this becomes

$$(10) \qquad T=-\frac{A}{VW}\,1n(1-C)$$

Equation 10 is an expression for the average time required to traverse an area, A, to any desired value of C, when the velocity, V, and the width, W, of the device are known.

The minimum time required to traverse an area, assuming no overlapping (as if the device were being steered unerringly by a human being), is given by

$$(11) \qquad T_{\min}=\frac{A}{VW}$$

An efficiency, Φ, may now be defined as the ratio of the time to achieve a value of C, divided by the minimum time; therefore dividing (10) by (11)

$$(12) \qquad \Phi=-1n(1-C)$$

The following table indicates values of this efficiency of the area covering device for various ratios of area traversed to total area, C.

Table I

Φ	C, percent
1.0	63.2
1.2	70
1.4	75
1.6	80
1.9	85
2.3	90
3.0	95
3.9	98
4.6	99
6.9	99.9

In order to more completely understand the manner of operation of a typical 2 ft. wide, area covering device of the present invention, consider a stand of grass a few inches high which is to be cut, said stand being circumscribed by a wire buried an inch or so below the surface of the ground which wire carries an alternating 60 cycle electric current. A self-propelled, freely operating device of the present type bearing a lawn-mower attachment approximately 2 ft. wide, which device is capable of perceiving the presence of the electromagnetic field produced by the alternating 60 cycle current, is placed within the area circumscribed by said wire, and actuated. The dedevice proceeds in a straight line cutting the grass as it proceeds, until it reaches and perceives said electromagnetic field, whereupon the device backs away from the electromagnetic field, makes a substantially random alteration in direction anywhere from 0° to 360°, and again proceeds in a substantially straight line cutting the grass as it proceeds. As has been indicated above, the inherent efficiency of said device in substantially completely traversing the prescribed area while operating continuously but substantially randomly is surprising. Thus, a device proceeding at the rate of 3 m.p.h. (about the average speed of a self-propelled conventional lawn mower), will mow an area measuring 100 ft. by 100 ft. to 95% completion in a period of only 57 minutes, and to 98% completion in only 1 hour and 14 minutes, i.e., in only 3 and 3.9 times respectively longer than the minimum time in which the same area could have been mowed by a conventional lawn mower while continuously guided unerringly by a human being.

The term, "barrier," which shall be utilized relatively extensively hereinafter in the specification and the claims, does not, as is clearly indicated above, necessarily denote a physical barrier such as a stone wall or a hedge or fence, but rather is utilized in its generic sense, i.e., to refer to a boundary of some sort, which of course can be physical as in the case of a stone wall but which can equally well be fulfilled by a ditch, or an electromagnetic field, or a change in texture of the soil, or a change in color in the surface of a paved road, or the presence of radioactivity

and so on. Accordingly, it is intended, and it should be so understood, that the term, "barrier," in the present specification and the claims appended hereto, be interpreted broadly and generically.

The term, "perceive," and its derivatives such as "perceived" and "perception," are likewise intended to be generic in nature. Thus, as utilized hereinafter, said terms refer generically to the perception of a wide class of "barriers" such as perception by touch, perception by sensing a change in wavelength of light, or by perception by sensing the presence of, or higher than average, radioactivity, and so on.

The device of the present invention comprises essentially

(a) means of locomotion, i.e., a source of propulsive force acting upon, for example, wheels,

(b) steering means acting upon said means of locomotion and capable of prescribing a relatively straight-line course,

(c) means for "percepting" a "barrier"; and

(d) means for prescribing substantially randomly, upon perception of a barrier, a new substantially straight-line course.

The above and other objects and advantages of the present invention will be more readily understood when reference is made to the accompanying drawings forming part thereof, wherein

FIGURE 1 is a diagrammatic, schematic view showing a side elecation of one embodiment of the present invention;

FIGURE 2 is a diagrammatic schematic view of part of FIGURE 1, taken along the lines **2—2** but going no further than lines **3—3**;

FIGURE 3 is a diagrammatic, schematic view of part of FIGURE 1 taken along the lines **3—3**;

FIGURE 4 is a diagrammatic, schematic view of part of FIGURE 1 taken along the lines **4—4**;

FIGURE 5 is a schematic view of program motor **25**;

FIGURE 6 is a schematic view of random angle selector motor **21**;

FIGURE 7 comprises a table of cam profiles;

FIGURE 8 is a schematic, diagrammatic electrical circuit plan of the device shown in FIGURES 1–7;

FIGURE 9 is a schematic, diagrammatic view showing a side elevation of another area covering device of the present invention;

FIGURE 10 is a schematic, diagrammatic electrical circuit plan of the device of FIGURE 9.

Referring now to the drawings, FIGURES 1–8, wherein like numbers refer to like parts, relate to an area covering device (hereinafter referred to as, the ACD) which ACD perceives upon contact, "barriers" comprising any solid obstacle having a height greater than about ¼ of its wheel diameter.

Contact plate **1** is connected by relatively free moving ball and socket connections **3** to vertically positioned support and electrode members **5** which in turn are connected to base **7** by means of relatively free moving ball and socket connections **9**. Base **7** is rigidly supported by main support **27** which passes through an aperture (not shown) at about the center of base **7**. All of members **5** are stabilized against deflecting from their vertical position except by the application of an external force upon plate **1**, by springs **11** which are attached by means of rings **13** and **15** to base **7** and posts **5** respectively. Thus, when plate **1** is deflected horizontally by the application of an external horizontal force thereto, thereby deflecting the tops of members **5** from their vertical positions, springs **11** cause members **5** and plate **1** to return to their respective original positions immediately upon the discontinuance of the force acting upon plate **1**.

At the top of support **27**, as seen most clearly in FIGURES 1 and 2, is affixed actuation switch **17** and the perception control center comprising four switches, **19**. Switches **19** consist of members **5** which serve as elec-

trodes, and electrically conductive hoops 21 which encircle members 5 and are supported by arms 23. All of arms 23 come to a common base (not shown) both physical and electrical behind actuation switch 17, wherein they are rigidly attached by any convenient means to main support 27. Switches 19 function in the following manner: When plate 1 is deflected horizontally by an external force such as would occur when plate 1 "runs into" a "barrier" such as a wall, the top of members 5 are likewise horizontally deflected. One (or more) of members 5 thereby contact one (or more) of hoops 21, closing one (or more) of switches 19 which closes the circuit to program motor 25 which in turn achieves a number of functions as will be described in detail hereinafter. Suffice it to say at this point that the parts numbering 1 to 23 can properly be referred to as the "perception means" in the ACD, as said parts acting together "perceive" the presence of a "barrier" upon contact, and send an electrical impulse which actuates program motor 25.

Referring now particularly to FIGURES 1 and 3, main support 27 which supports the entire perception means (parts 1 to 23), is rigidly affixed to main base 26. Base 26 likewise supports steering motor 29 program motor 25, random angle selector motor 31 and power supply means 33.

Base 27 is in turn (as can be appreciated most readily by reference to FIGURES 1 and 4) supported by three discs 35, each of which is mounted upon a wheel 37. Wheels 37 are driven by chains 39 which in turn are actuated by electric drive motors 41 which derive their power from power supply means 33. Thus, components 33–41 can aptly be referred to as the "locomotion means" of the ACD of FIGURE 1.

Chain 43 as best seen in FIGURE 4 engages discs 35 and serves to maintain the synchronization of wheels 37. In addition chain 43 when actuated by drive pinion 45 serves to rotate all of discs 35 equally and proportionately which in turn alters the alignment of each of wheels 37 equally. Thus, once wheels 37 have been aligned, any rotation of drive pinion 45 serves to turn all of wheels 37 equally, while the extent of rotation of drive pinion 45 determines the new alignment of the wheels and therefore the new direction upon which the ACD will embark. Drive pinion 45 is actuated by constant speed steering motor 29 which in turn is actuated for a random period of time ranging between zero time and sufficient time to cause wheels 37 to turn 360 degrees, by program motor 25 which is actuated by the "perception means" discussed heretofore.

Referring now to FIGURE 8, the electrical circuit plan, the overall operation of the ACD will be more readily understood. The closing of actuation switch 17 actuates the ACD by actuating the "locomotion means" (parts 33–41). The ACD moves in a relatively straight line in the direction dictated by the alignment of wheels 37. When the ACD strikes a barrier (any physical obstacle higher than about ¼ of its wheel diameter), plate 1 of the perception means is deflected horizontally, thereby as heretofore explained in detail, closing switch(es) 19 and allowing electrical current to flow to program motor 25 which is thereby actuated. (Now see FIGURE 5.) The actuation of motor 25 causes the rotation of rod 51 bearing cams 1, 2, 3 and 4 each of which serves to trip one or more electrical switches as explained below:

Cam 1, because of its shape, as will be more readily appreciated by reference to the table of profiles (FIG. 7), immediately closes and maintains closed switch 53, (which is normally open, as shown) thereby providing for motor 25 a source of electric current (note even when switch(es) 19 opens) until cam 1 has made one complete revolution.

While cam 1 is in the process of making one complete revolution, cam 2 (a) simultaneously (see table of cam profiles) momentarily shifts single pole double throw switches 55 and 57 from position *a* (their normal position) to position *b*, thereby reversing the current flow to motors 41 and causing the ACD to back up along its previous course of travel (note, this allows plate 1 to return to its original position thus opening switch(es) 19), and (b) then returns switches 55 and 57 to position *a* thus in effect returning switches 57 and 55 to their normal positions thereby stopping the backward motion of the ACD.

In the meantime, however (or at least simultaneously with the return of switches 55 and 57 to position *a* (see table of cam profiles), cam 3 opens switch 59 (which is normally closed, as shown) for the duration of this cycle of the program motor (i.e. until all of cams 1–4 have made one complete revolution and have returned to their original positions, that is, the position held prior to actuation of motor 25) thus preventing electric current from reaching drive motors 41 until said cycle has been completed.

In the meantime, i.e. after (or just as—see table of cam profiles), cam 2 has returned switch 55 to position *a* and cam 3 has opened switch 59, cam 4 closes switch 61. Random angle selector motor 31 which has been in operation continuously since the ACD was actuated, and which motor drives rod 65 bearing cam 5, which cam (see table of cam profiles) during 180° of the sweep of its surface closes switch 67, and during the other 180° sweep of its surface opens switch 67, causes switches 67 and 61 to close for some completely random period of time. The reason why switch 67 will be closed for a completely random period of time will be readily appreciated when it is considered that cam 4 and cam 5, which continuously revolves while the ACD is in operation, are not synchronized in any way, except that program motor 25 and selector motor 31 preferably have approximately the same speed. Thus, when cam 4 causes switch 61 to close, the position of cam 5 at that particular moment is purely one of chance. Thus, clearly the period of time during which switches 67 and 61 will remain closed simultaneously during any one revolution of cam 4 is purely one of chance. Thus the period of time for which steering motor 29 is actuated and the period of time during which driving pinion 45 rotates is purely one of chance. It follows that the new orientation of wheels 37 will likewise be one of chance.

It is pointed out that for proper operation of the ACD, the circumference of cam 5 must be synchronized with the speed of steering motor 29 so that the maximum period of time switch 67 can remain closed during any one revolution of cam 5 will be just sufficient to permit actuation of steering motor 29 long enough to turn wheels 37 exactly 360°. While some variation can be tolerated in the relationship of the size of cam 5 to the speed of steering motor 29, for best results, it is essential that the above directions be followed precisely.

Referring now to the table of cam profiles, it will be seen that after all the aforesaid events have occurred, and as cams 1, 2, 3 and 4 each complete one revolution, (a) switch 53 opens discontinuing operation of motor 25, and (b) switch 59 closes thereby actuating the "locomotion means" and causing the ACD to proceed along its new course in accordance with the new alignment of wheels 37.

Needless to say, none of the materials of construction of the ACD are generally critical. Plate 1 for example can be constructed of any suitable material such as plastic or metal but is preferably constructed of plastic. Bases 7 and 26 and discs 35 can comprise plastic, wood or metal but preferably comprise metal. The construction of supports 5 and 27 likewise is not critical, metal being completely suitable therefor. Wheels 37, chains 39 and 43, and electric motors 41, 25, 29 and 31 are standard articles of commerce and require no explanation. Power supply means clearly can comprise any conventional dry or wet cell battery (i.e.) the particular size required being dictated primarily by the size of motors 25, 29, 31 and particularly 41, and the gross weight of the ACD as well as

the texture of the terrain upon which the ACD operates. Clearly other power supply means such as a gasoline driven or solar generator can be utilized instead of batteries.

Particularly, it is intended, and it should be clearly understood, that the present invention is not limited to the particular combination of the particular components described above but rather involves a broad new concept in the area covering devices. The essential requirements of an ACD within the scope of the present invention are:

(a) means for locomotion;

(b) steering means capable of prescribing a relatively straight-line course;

(c) means for "percepting" a "barrier" and

(d) upon the "perception" of a "barrier," means for prescribing substantially randomly a new straight-line course.

Thus, many changes can be made in the above-described ACD without departing from the scope of the invention. For example, electric motors **41** can be replaced by gasoline driven motors or by a single gasoline driven motor which distributes power to the wheels by means of a conventional pinion and idler arrangement.

Moreover, it should be clearly understood that the particular perception means (components **1–23**), program motor (**25**), and random angle selector motor described above are likewise not critical to the ACD's of the present invention. This will be readily appreciated in accordance with the following description concerning FIGURES 9 and 10 wherein an electronically actuated and controlled ACD within the scope of the present invention is set forth:

Upon approaching a conductor on or in the ground carrying, for example, a 60 cycle alternating current, a current is induced in coil **100** which is mounted on the ACD parallel to the ground. Said induced current actuates transistor **102** which in turn energizes solenoid **104** which closes switch **106**. The closing of switch **106** allows current to flow to solenoids **108** and **110** which thereby become energized. The energizing of solenoid **108** causes switch **112** to move from position *a* (its normal position) to position *b* thereby causing capacitor **114** to become charged.

The energizing of solenoid **110** causes switch **116** to move from position *c* (its normal position) to position *d*, thereby reversing the direction of current flow to electric motors **118** and causing the ACD to back up along its previous line of travel until the current induced in coil **100** by the magnetic field is insufficient to maintain solenoid **104** energized. Thereupon, switch **106** opens, switch **116** returns to position *c* and the backward motion of the ACD ceases.

Meanwhile, however, as soon as switch **106** opens, solenoid **108** is deenergized and switch **112** moves back to its normal position *a*. Thereupon, capacitor **114** begins to discharge, energizing solenoids **120** and **122**.

Solenoid **122** opens switch **124** which is normally closed thereby preventing electric current from flowing to motors **118**.

Solenoid **120** causes switch **126** to move from position *e* (its normal position) to position *f* which allows capacitor **128**, which is normally charged, to a substantially random degree by random signal generator **130** to discharge through transistor **132** thereby energizing solenoid **134** which in turn closes switch **136**, which is normally open, allowing electric current to flow to steering motor **138**. The length of time that switch **136** remains closed, and accordingly that motor **138** is actuated, is directly dependent upon the length of time that it takes for capacitor **128** to discharge which in turn is directly dependent upon the extent to which capacitor **128** was charged prior to the moving of switch **126** from position *e* to position *f*, which in turn is purely one of chance as random signal generator **130** is continuously actuated during actuation of the ACD and is thus continuously substantially randomly altering the charge on capacitor **128**. Needless to say, while some variation is possible, it is preferable that the extent of the charge in capacitor **128** vary between about no charge and that charge required to maintain switch **136** closed long enough for steering motor **138** to cause wheels **37** to make one complete revolution.

Many other changes can be made in the above-described ACD without departing from the spirit or scope of the present invention. For example, while both the ACD's described above have been provided with means to allow them to back up because many advantages are achieved thereby, it clearly is possible to construct an ACD which does not back up after perceiving a barrier. Thus, it is intended that the above description and drawings be considered as illustrative and as in no way limiting the scope of the present invention.

What we claim is:

1. An area covering device comprising at least three wheels, means for driving said wheels, means for maintaining said wheels aligned, means for percepting a barrier, means for stopping said device after perception of a barrier, means for causing said device to back up substantially along its previous course of travel after coming to a stop, means for causing said device to cease backing up when the perception means is out of range of said barrier, means for substantially randomly altering the alignment of said wheels after said device has ceased backing up, and means for driving said device forward after realignment of said wheels.

2. The area covering device of claim **1** wherein said means for percepting a barrier comprise means for percepting an electromagnetic field.

3. The area covering device of claim **1** wherein said means for percepting a barrier comprise means for percepting a solid barrier.

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