

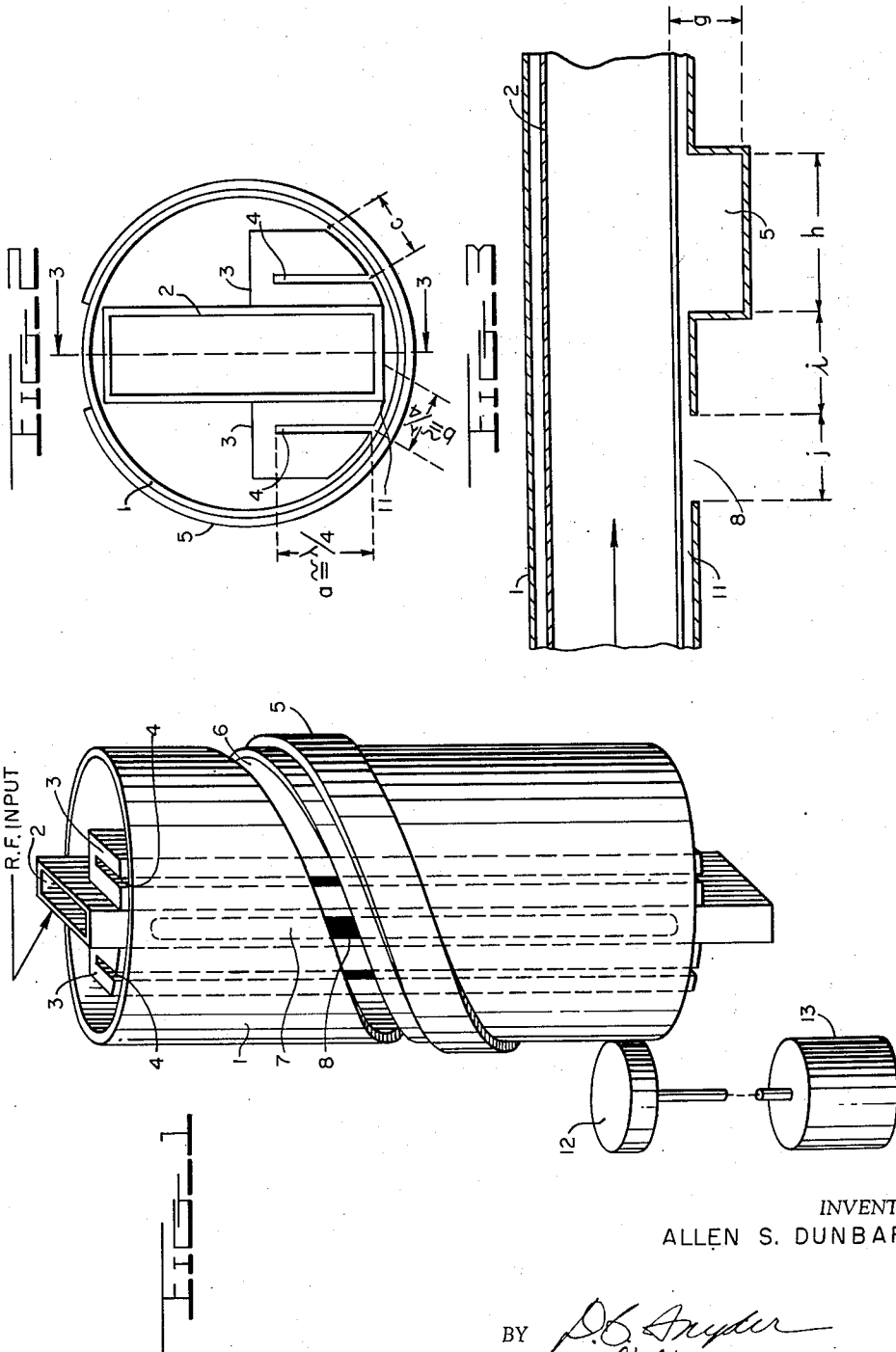
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A. S. DUNBAR
HELICAL SLOT SCANNER

2,670,436

Filed May 3, 1950

2 Sheets-Sheet 1



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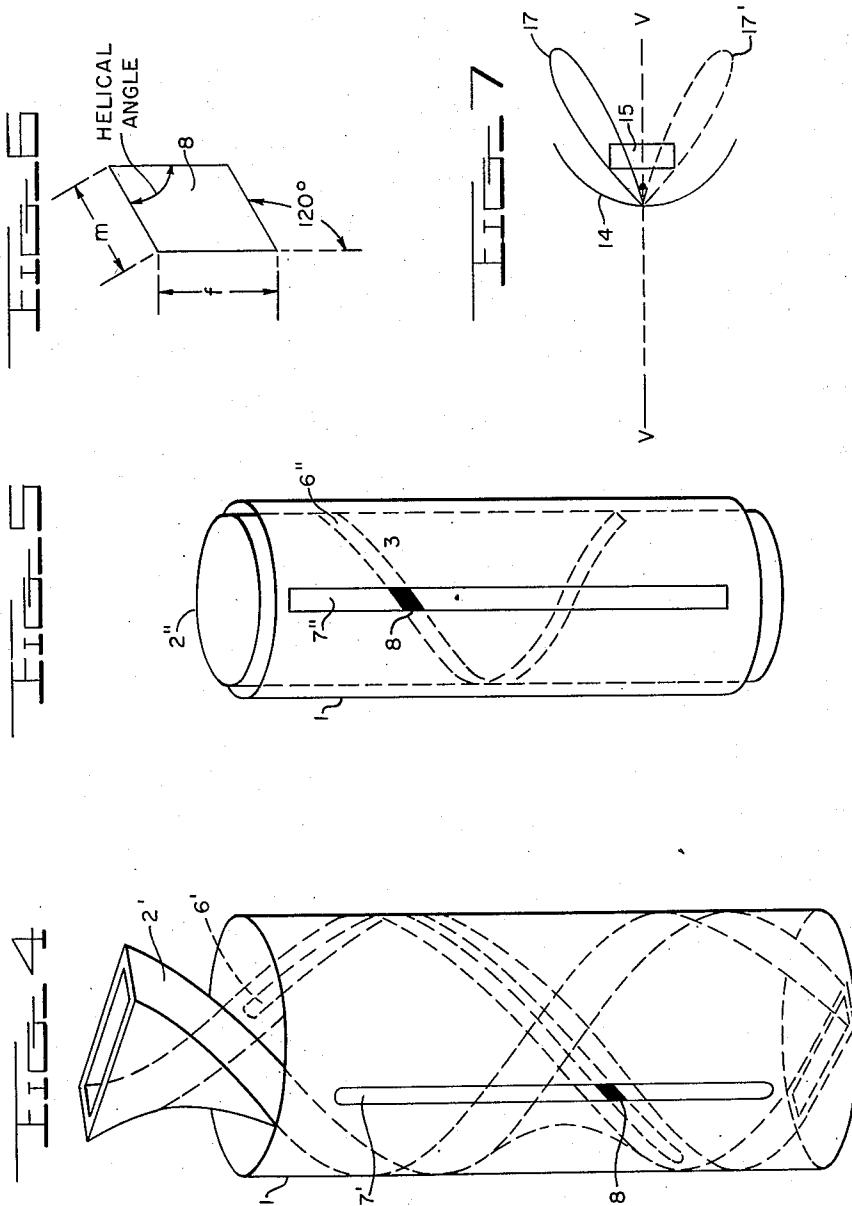
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HELICAL SLOT SCANNER

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This invention relates to antennas for use in propagating electromagnetic waves of high frequency.

More specifically this invention relates to a novel wave guide slot scanning radiator. In the preferred application, the scanner is used as a feeding means for a focusing device wherein the feeding means is caused to propagate electromagnetic energy toward the reflector or electromagnetic lens in a manner such that the point from which the energy is radiated moves along a straight line.

In angle tracking radar systems and the like, the speed at which the antenna can scan a given predetermined area is of great importance. To this end, it has been found necessary to reduce the inertia of the moving parts of the antenna by keeping the relatively large focusing apparatus stationary, and by moving only the point from which the feeding means radiates electromagnetic energy toward the focusing apparatus. In so doing, a beam results which in effect quickly scans a given predetermined angle just as if the focusing device and feeding means were being moved together as a unit.

In general it is desirable to have the rate of scan not only of a high value, but substantially uniform as well. In the prior art devices, this was generally not readily possible.

Accordingly, a principal object of the invention is to provide electromagnetic wave propagating apparatus wherein the point from which the electromagnetic energy emanates moves quickly and at a substantially uniform rate.

Another object of the invention is to provide electromagnetic wave propagating apparatus wherein the point from which the electromagnetic energy emanates moves quickly along a straight line.

Fig. 1 is a perspective view of the propagating apparatus which is the preferred embodiment of the invention.

Fig. 2 is an overhead view of the embodiment of Fig. 1.

Fig. 3 is a cross-sectional view of Fig. 2 along section line 3-3.

Fig. 4 is a perspective view of another embodiment of the invention.

Fig. 5 is a perspective view of still another embodiment of the invention shown in simplified form.

Fig. 6 shows the important dimensions of propagating opening 8.

Fig. 7 shows the relationship between a parabolic focusing means and the slot scanning feeder of the present invention.

Basically the present invention consists of a wave guide 2 (these reference characters refer generally to all the figures) located within a hollow right circular cylinder 1 where one of these last two mentioned members has a long, narrow opening or slot 7 and the other member has a helical slot or opening 6. The wall members having the slots are in contiguous (but not in contact) relation so that at the point where the openings 6 and 7 cross each other a radiating aperture 8 is formed. The member containing the helical slot or opening 6 is caused to rotate by means of a suitable driving mechanism 13, the radiating aperture 8 formed at the junction of the helical slot 6 and the straight slot 7 will move at a predetermined rate until it reaches the end of the straight slot whereupon it will reappear at the opposite end of the straight slot and then begin to repeat the same motion. To prevent a substantial interruption of the flow of energy through radiating aperture 8 when the aperture has raised to the end of the straight slot 7 the helical slot is made to extend over substantially a 360 degree surface of the cylinder in which it is formed.

Due to the fact that there is a space or gap 11 between the wave guide 2 and the outer cylinder 1, choke means later described, must be provided to effectively prevent energy from leaking from the slot 7 of the wave guide 2 into this opening.

The dimensions of the radiating aperture 8 appreciably effects the amount of energy which is coupled from the wave guide 2. Generally the periphery of the aperture 8 should be in the vicinity of one (or a multiple thereof) free space wave length. The shape of the opening is not critical, however, resonance being the important objective. With such an opening, however, only about $\frac{1}{2}$ of the incident power could be extracted from the wave guide 2. It was found that by adding a helical channel 5 to the inner surface of cylinder 1 adjacent the helical slot or opening 6 (see Figs. 1-3), over 90 percent of the incident power could be extracted by the propagating opening 8 over its entire range of movement. With such a modification the dimensions of the radiating aperture 8 were modified to give best results. The effect of such a helical channel was to shunt the wave guide 2 adjacent the moving aperture 8 with a zero impedance so that substantially all of the incident energy went out of aperture 8 rather than 50 percent of the incident energy continuing down the wave guide 2. Such a shunting means also has the advantage of making the amount of energy emitted from

the aperture 8 substantially independent of its position. This is because the portion of the wave guide 2 starting from the helical channel 5 and extending to the end of the wave guide 2 remote from the end of the wave guide 2 which conducts the incident wave to the radiating aperture 8, is effectively shunted out of the circuit. It should be clear that the helical channel is not very readily applicable to the embodiments of Figs. 4 and 5 where the helical slot 6 is not located on the outer cylinder 1. Of course, in the embodiment of Fig. 5, the helical slot 6'' could be placed in the outer cylinder 1 instead of on wave guide 2'' and thus make the addition of a helical channel readily practicable.

Since rectangular wave guides are more practicable, and because of the increased output possible with the helical channel 5, Fig. 1 is the preferred embodiment of the invention.

Referring more particularly to Figs. 1-3, the outer cylinder 1 has a narrow helical slot or opening 6. Within the cylinder 1 is located a rectangular wave guide 2 with a long, relatively straight and narrow slot or opening 7. The slot 7 is placed in the narrow side of the wave guide 2 and is parallel to the axis of the wave guide 2. The slot 7 could be placed on the wide side of wave guide 2, but only with added difficulty and complications. The overlapping slots 6 and 7 should be contiguous to each other and because this is more readily possible with slot 7 cut in the narrow side of wave guide 2, and because energy is more readily coupled out of the narrow side of the wave guide by such a slot, the slot position as shown in Fig. 1 is the preferred one. Of course, slot 7 need not be parallel to the axis of wave guide 2, but for purposes of obtaining more even power transfer from the moving propagating opening 8, such a parallel relationship is preferred.

The axis of wave guide 2 is shown parallel to the axis of cylinder 1 since this allows the overlapping slots to be more closely adjacent each other.

As seen more clearly in Fig. 2, wave guide 2 is not in contact with the cylinder 1 since cylinder 1 is to be rotated. Rotation is accomplished by means of a gear means 12 which in turn is rotated by a motor 13. When cylinder 1 is rotated it can be seen that radiating aperture 8 moves from one end of slot 7 to the other and then suddenly appears at the end of slots 7 from which it originated. If motor 13 revolves at a uniform rate, then propagating opening 8 moves at a uniform rate also. Because of the fact that opening 8 always moves in the same direction, the beam which is obtained when the opening is directed toward a focusing device will sweep by a given target at a substantially constant rate.

Since wave guide 2 is not in direct and close contact with the cylinder 1, unless choke means 3 are provided which will effectively close or block off this gap 11, appreciable energy will leak from wave guide 2 through slot 7 into the inner portion of cylinder 1 and thus be wasted in addition to causing undesirable effects on the field distribution in wave guide 2. Choke 3 consists of a pair of solid metallic bars each located on one side of wave guide 2 with a choke groove 4 cut in each which run parallel to the long narrow slot 7.

As shown in Fig. 2, dimensions *a* (depth of choke groove) and *b* are about one-quarter guide wave lengths at the operating frequency. The choke 3 has the same effect as if a solid piece of

metal were placed between slot 7 and the inner wall of cylinder 1. Satisfactory results were obtained with the following choke dimensions:

a, .441''
b, .441''
c, .625''

Frequency, 9,375 megacycles

Width of choke groove, .063''

Clearance between choke and cylinder, .031''

Width of slot 7, .250''

If the embodiment of Fig. 1 were to be used without channel 5, then the total periphery of propagating opening 8 should be in the neighborhood of one free space wave length.

Fig. 3 shows a cross-sectional view of Fig. 2 along section line 3-3 showing the relation of the helical channel 5 and radiating aperture 8. It is to be noted that channel 5 is located the same distance from helical slot 6 at all points so that it always has the effect of shunting wave guide 2 with a low impedance no matter what the position of radiating aperture 8 may be. Besides having this shunting effect, it must be so placed as to provide a proper impedance termination in wave guide 2 in the vicinity of channel 5. One group of dimensions found satisfactory are as follows (refer to Fig. 3):

g=depth of helical channel=1.18 cm.

h=wide dimension of channel 5=.900''

i=distance of helical channel from propagating opening 8=.374''

j=length of radiating aperture=1.72 cm.

Width of radiating aperture=width of slot 7 (not shown in Fig. 3)=.250'' (since helical angle=60 degrees, the peripheral width of radiating aperture was .250×1/sine 60 degrees=.288)

The length of narrow dimension of wave guide 2 (not shown in Fig. 3)=.400''

Since the helical angle was 60 degrees, the peripheral width *m* (see Fig. 6) of radiating aperture

$$8 = \frac{.250}{\sin 60} = .288''$$

frequency=9,375 megacycles

The above dimensions are not critical and many variations can be made without deviating from the scope of the invention.

Of course, a circular wave guide could be substituted for rectangular wave guide 2.

Fig. 4 discloses another embodiment of the invention where the helical groove 6'' is located on the wave guide and the straight slot 7'' is located on the cylinder. In order to place helical slot on a rectangular wave guide, the side of the wave guide containing the slot must be twisted to follow a helical surface.

Since the radiating aperture 8 is to be moved along a straight line, the wave guide with the helical groove must be rotated. As previously explained, this embodiment is not very well adapted for use with a helical channel 5 such as found in the preferred embodiment of Fig. 1.

Fig. 5 shows a third embodiment where a cylindrical wave guide 2'' is used instead of a rectangular wave guide. Here again, the wave guide containing the helical groove 6'' is rotated. In the embodiments of Figs. 4 and 5, choke grooves (not shown) will follow along the sides of the helical grooves 6' and 6'' respectively.

As shown in Fig. 7, the linear feeding device 15 forming this invention is mounted so that the radiating aperture moves along a straight line which is perpendicular to a plane *v-v* which

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passes through the focal point of the parabolic focusing means 14 and also bisects the parabolic focusing means 14. Then the radiating aperture 8 directs electromagnetic energy toward reflector 14 as it moves along the before mentioned line, the resultant beam gradually moves from the position of beam 17 to that of 17'.

The embodiments disclosed in the drawing and specification are exemplary only and many modifications can be made without deviating from the scope of the invention.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

What is claimed is:

1. Electromagnetic propagating apparatus comprising in combination: a wave guide having a long, narrow slot in the wall thereof, a hollow cylinder surrounding said wave guide and having its inner wall surface in contiguous relation to the wave guide wall forming the said slot, said hollow cylinder also having a long narrow slot in the wall thereof, one of said slots being relatively straight and the other slot following a helix, the two slots thereby overlapping to form a radiating aperture, a choke means extending along the sides of said wave guide slot for effectively placing a low impedance across the finite gap between the sides of said wave guide slot and the contiguous inner surface of the cylinder, means coupled to the member containing the helical slot for rotating same thereby causing said radiating aperture to traverse a straight line.

2. Electromagnetic propagating apparatus comprising in combination: a wave guide having a long, straight, narrow opening in its wall, a hollow cylinder surrounding said wave guide and having its inner wall surface in contiguous relation to the portion of the wall of said wave guide which is adjacent said slot, said hollow cylinder having a helical slot in its wall whereby the said openings overlap to form a radiating aperture, a choke means extending along the sides of said wave guide slot for effectively placing a low impedance across the finite gap between the sides of said wave guide slot and the contiguous inner surface of the cylinder, means coupled to said cylinder for rotating same thereby causing said radiating aperture to traverse a straight line.

3. Electromagnetic propagating apparatus comprising in combination: a wave guide having a long, straight, narrow opening in its wall, a hollow cylinder surrounding said wave guide and having its inner wall surface in contiguous relation to portion of the wall of said wave guide which is adjacent the said opening, said hollow cylinder having a substantially helical slot or opening in its wall whereby the said openings overlap to form a radiating aperture, and choke means extending along the sides of said wave guide slot for effectively placing a low impedance across the finite gap between the sides of said wave guide slot and the contiguous inner surface of the cylinder.

4. Electromagnetic propagating apparatus comprising in combination: a wave guide having a long, narrow slot in its wall, a hollow cylinder surrounding said wave guide and having its inner wall surface in contiguous relation to the wave guide wall forming the said slot, said hollow cylinder also having a long narrow slot in its wall, one of said slots being relatively straight and the other slot following substantially along a helix,

the two slots thereby overlapping to form a radiating aperture, a choke means extending along both sides of said wave guide slot for effectively placing a low impedance across the finite gap between the sides of the said wave guide slot and the contiguous inner surface of the cylinder.

5. Electromagnetic propagating apparatus comprising in combination: a wave guide having a long, narrow slot in its wall, a hollow cylinder surrounding said wave guide and having its inner wall surface in contiguous relation to the wave guide wall forming the said slot, said hollow cylinder also having a long narrow slot in its wall, one of said slots being relatively straight and the other slot or opening following substantially along a helix, the two slots thereby overlapping to form a radiating aperture, a choke means comprising a pair of grooves members extending along both sides of said wave guide slot, said grooves extending along the entire length of said wave guide slot and communicating with the finite space between the sides of the wave guide adjacent the wave guide slot and the contiguous inner surface of the cylinder, the depth of the said grooves being such that a low impedance exists between the sides of the wave guide slot and the contiguous inner surface of the cylinder.

6. Electromagnetic propagating apparatus comprising in combination: a rectangular wave guide having a long, narrow slot or opening in its narrow side, a hollow cylinder surrounding said wave guide and having its inner wall surface in contiguous relation to the wave guide wall forming the said slot, said hollow cylinder also having a long narrow slot in its wall, one of said slots or opening being relatively straight and the other slot or opening following substantially along a helix, the two slots thereby overlapping to form a radiating aperture, whereby rotation of the member containing the helical slot causes said radiating aperture to traverse a straight line and choke means extending along the sides of said wave guide slot for effectively placing a low impedance across the finite gap between the sides of said wave guide slot and the contiguous inner surface of the cylinder.

7. Electromagnetic propagating apparatus comprising in combination: a rectangular wave guide having a long, straight, narrow opening in its narrow side, a hollow cylinder surrounding said wave guide and having its inner wall surface in contiguous relation to the portion of the wall of said wave guide which is adjacent the said opening, said hollow cylinder having a helical slot or opening in its wall whereby the said openings overlap to form a radiating aperture, means coupled to said cylinder for rotating same thereby causing said radiating aperture to traverse a straight line and choke means extending along the sides of said wave guide slot for effectively placing a low impedance across the finite gap between the sides of said wave guide slot and the contiguous inner surface of the cylinder.

8. Electromagnetic propagating apparatus comprising in combination: a wave guide having a long, straight, narrow opening in its wall, a hollow cylinder surrounding said wave guide and having its inner wall surface in contiguous relation to portion of the wall of said wave guide which is adjacent the said opening, said hollow cylinder having a substantially helical slot or opening in its wall whereby the said openings overlap to form a radiating aperture, a helical channel formed on the inner surface of said cyl-

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inder and running parallel to the helical slot or opening of said cylinder, said channel being of such dimension that it reflects a low impedance across said wave guide on one side of the radiating aperture.

9. Electromagnetic propagating apparatus comprising in combination: a wave guide having a long, straight, narrow opening in its wall, a hollow cylinder surrounding said wave guide and having its inner wall surface in contiguous relation to portion of the wall of said wave guide which is adjacent the said opening, said hollow cylinder having a substantially helical slot or opening in its wall whereby the said openings overlap to form a radiating aperture, means coupled to said cylinder for rotating same thereby causing said radiating aperture to traverse a straight line, a first choke means comprising a pair of grooves members extending along both sides of said wave guide slot, said grooves extending along the entire length of said wave guide slot and communicating with the finite space between the sides of the wave guide adjacent the wave guide slot and the contiguous inner surface of the cylinder, the depth of the said grooves being such that a low impedance exists between the sides of the wave guide slot and the contiguous inner surface of the cylinder, a helical channel located on the inner surface of said cylinder and running parallel to the helical slot of said cylinder, said channel being of such dimension that it reflects a low impedance across

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said wave guide on one side of the radiating aperture.

10. Electromagnetic propagating apparatus comprising in combination: a wave guide having a long, narrow slot in the wall thereof, a hollow cylinder surrounding said wave guide and having its inner wall surface in contiguous relation to the wave guide wall forming the said slot, said hollow cylinder also having a long narrow slot in the wall thereof, one of said slots being relatively straight and the other slot following a helix, said helical slot making substantially a complete revolution, the two slots thereby overlapping to form a radiating aperture, means coupled to the member containing the helical slot for rotating same thereby causing said radiating aperture to traverse a straight line and choke means extending along the sides of said wave guide slot for effectively placing a low impedance across the finite gap between the sides of said wave guide slot and the contiguous inner surface of the cylinder.

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References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
2,371,963	La Pierre	Mar. 20, 1945
2,480,181	Breen	Aug. 30, 1949
2,510,200	Thompson	June 6, 1950
2,555,443	Harvey	June 5, 1951