Nov. 2, 1948. B. R. HUBBARD 2,452,570

COMPRESSIONAL WAVE TRANSMITTING AND RECEIVING DEVICE

Filed May 5, 1933 2 Sheets-Sheet 1

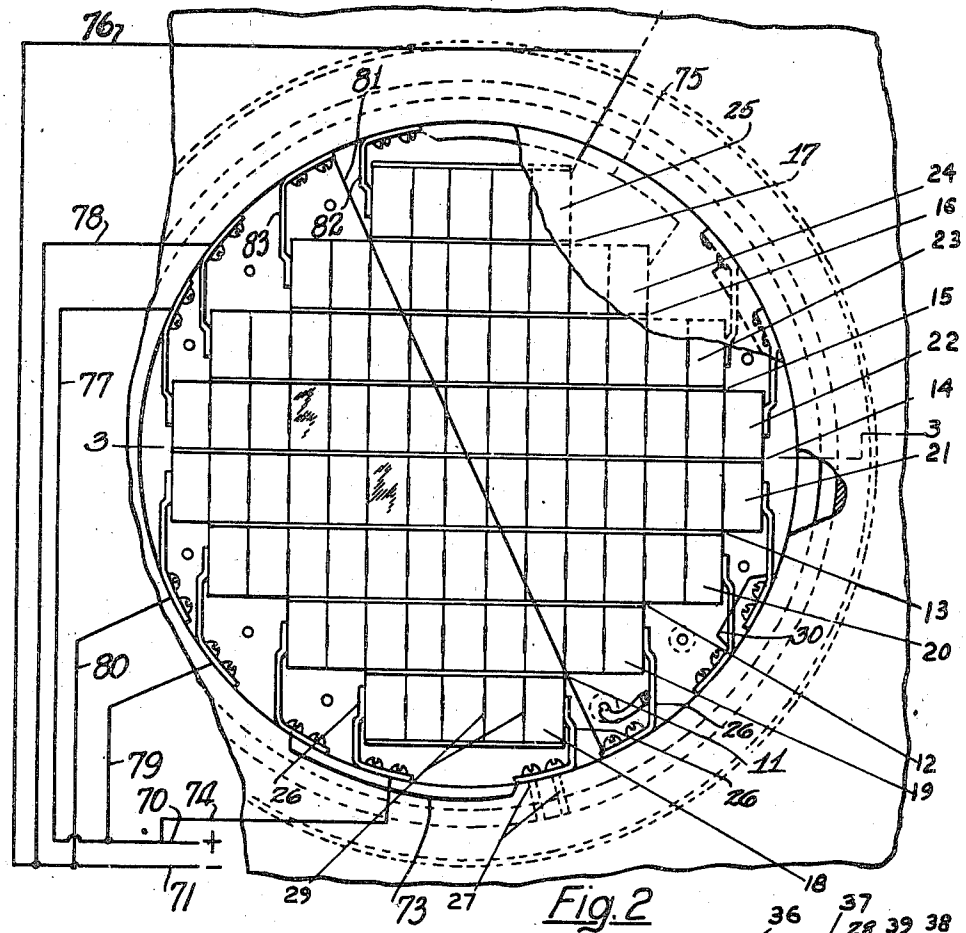


Fig. 2

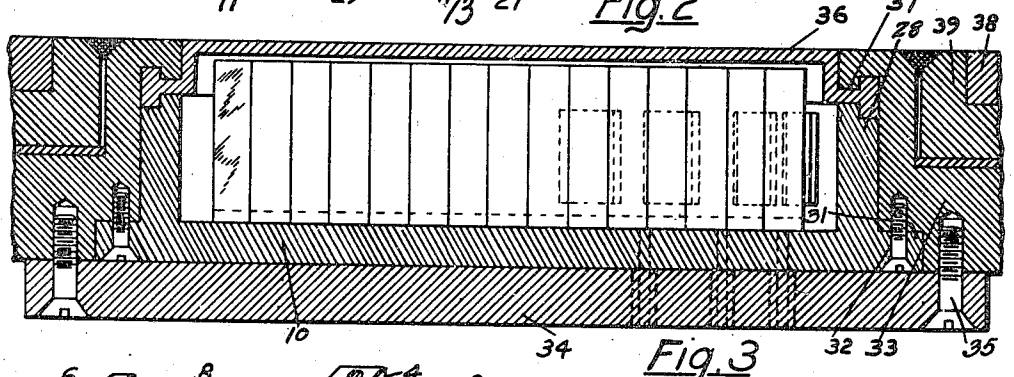


Fig. 3

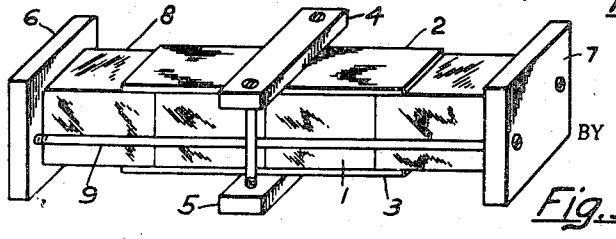


Fig. 1

INVENTOR.
Beverly R. Hubbard
BY
Ezekiel Wolf
ATTORNEY.

Nov. 2, 1948. B. R. HUBBARD 2,452,570

COMPRESSIONAL WAVE TRANSMITTING AND RECEIVING DEVICE

Filed May 5, 1933 2 Sheets-Sheet 2

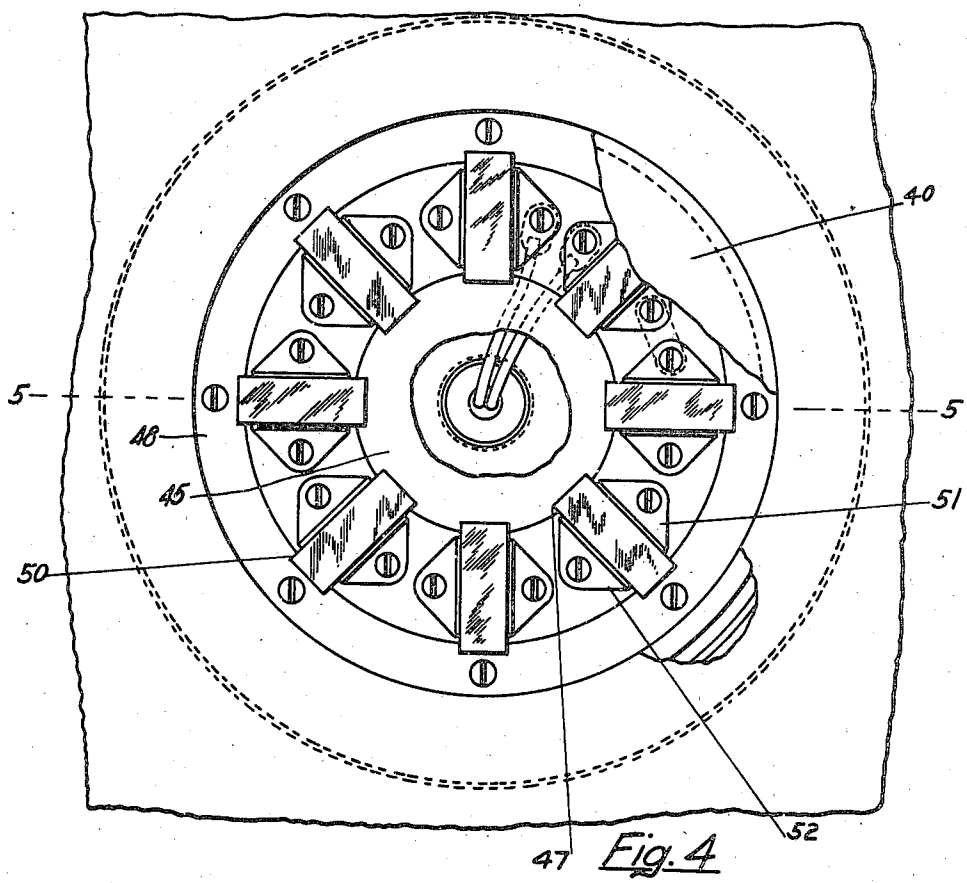


Fig. 4

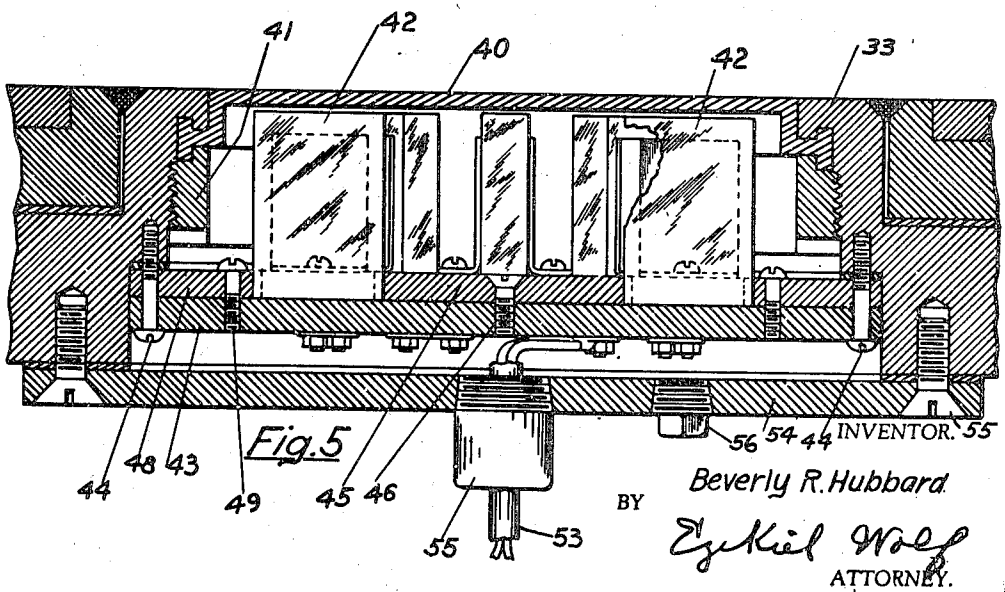


Fig. 5

INVENTOR.
Beverly R. Hubbard
BY
Ezekiel Wolf
ATTORNEY.

Patented Nov. 2, 1948

2,452,570

UNITED STATES PATENT OFFICE

2,452,570

COMPRESSIONAL WAVE TRANSMITTING AND RECEIVING DEVICE

Beverly R. Hubbard, Melrose, Mass., assignor, by mesne assignments, to Submarine Signal Company, Boston, Mass., a corporation of Delaware

Application May 5, 1933, Serial No. 669,477

6 Claims. (Cl. 177—386)

1

The present invention relates to the use of compressional wave transmitting and receiving apparatus, and more particularly to the type in which resonant and non-resonant piezo-electric crystals are employed.

The present invention employs a crystal of the type which it has been found possible to grow under artificial conditions as contrasted with crystals of the type of quartz or tourmaline which are mined and afterwards cut for the purposes desired. In this group of crystals the present invention is concerned more particularly with the use of Rochelle-salt crystals whose piezo-electric effect is more pronounced in general than crystals of other types.

While the present invention is concerned with the use of resonant and non-resonant crystals, I prefer to employ a resonant crystal resonant in the compressional axes. Crystals of this type are somewhat uncommon and prior to the present invention have never been generally used with resonant frequencies in the range employed in the present invention. I have determined that in the supersonic range in submarine listening the most advantageous range of frequencies to use are those about, or just above, the limit of audibility, between the range of 20,000 to 40,000 cycles per second. Within this range the directive effect gained by the use of a plurality of crystals operating together to produce a compressional wave beam balances or more than balances the natural attenuation of the high frequency in water so that the energy transmitted remains substantially at such a value that communication, signaling and soundings are easily accomplished.

In prior apparatus resonant crystals at this frequency have never been employed and in the present invention I have devised methods by which resonant crystals of a composite of two or more crystals may be used which have a resonance in the compressional axes. Crystals of this type may be made by cementing similarly cut crystals together so that their compressional axes are aligned and the corresponding electric axes are parallel to one another.

In the present application the resonance of the structure may be broadened or narrowed, depending upon the loading which the crystals may have. In the present case the loading effected by

2

the cover and the back plate is so chosen that the range covered is between 20,000 and 40,000 cycles.

Further, in the present invention the crystals may be mounted on a heavy back plate and distributed radially about a central point or they may be mounted adjacent one another in a mosaic pattern. Further, the exposed ends of the crystals may be in contact with a soft rubber cover or diaphragm, or they may be just out of contact with such a cover and the space between them and the cover filled with some liquid under pressure equivalent to the external water pressure or under natural atmospheric pressure. Such liquid can be castor oil or some other suitable substance in which the crystal will not be dissolved.

In the structures in which the crystals are grouped together the desired impedance may be obtained by connecting the crystals in proper series and parallel combination to produce the desired impedance in the circuit to which the receiver is connected.

For a voltage-operated device, such as a vacuum tube circuit, I prefer to use the crystals in a series combination in which by reason of the series combination the voltage generated will be high. In addition to this the receiver may preferably be connected directly into the grid circuit so that the impedance of the grid circuit, which can be made very high, will be properly matched.

When the apparatus is to be used in connection with a vacuum tube circuit in which the input between the receiver and the circuit is effected through a transformer, it is preferable either to use a parallelly connected combination of the crystals or a parallel series combination in matching the circuit impedance.

It should be noted that the present receiver is a directional receiver particularly because of the dimension of the receiving surface as compared with the wave length of the wave to be received in the compressional medium. Other than this, it should be noted that it is a pressure type of receiver and but for the directional effect gained through the large dimension of the receiving surface with the wave length of the compressional wave it will receive as well from a direction at an angle to the normal as in the direction of the normal itself. A single crystal, therefore, may be used as a non-directional receiver while

the plurality of crystals associated together may be used as a directional receiver.

The present invention will be more fully described in connection wtih the drawings illustrating the invention in which Fig. 1 shows a composite crystal formed of a plurality of crystals; Fig. 2 shows a plan view of a crystal receiver or transmitter having a group of crystals mounted to form a number of rows; Fig. 3 shows a sectional view along the line 3—3 of Fig. 2; Fig. 4 shows a plan view of a modification of the device shown in Fig. 2; and Fig. 5 shows a sectional view along the line 5—5 of Fig. 4.

In Fig. 1, as has been explained above, the composite crystal 1 may be formed by the use of proper cement between the individual crystals. In an elongated crystal having the compressional axis *a* tuned to the desired resonant frequency within the receiving range of 20,000 to 40,000 cycles, the resonance may be made very sharp by using the crystal as a longitudinally freely oscillating structure.

The compressional axis of the crystal is the axis in which the greatest elongation and contraction take place. This axis is at an angle of 45 degrees to the so-called B and C axes which form with the A axis the three perpendicular axes of the crystal. If a crystal is cut in a rectangular polyhedral form with the longer sides parallel to the B and C axes, the compressional axis, so-called, will be defined as at an angle of 45 degrees to the B or C axis and perpendicular to the A or electric axis. If a potential is applied between the opposite surfaces at the ends of the A or electric axis and the crystal is held at one end along a direction parallel to the B or C axis, the crystal at the free end will move in a direction parallel to the axis that is held. It is obvious from this that the maximum elongation and contraction will occur diagonally across the crystal, and, therefore, if the crystal is cut diagonally at an angle of 45 degrees to the B and C axes, the compressional axis will be parallel to the polyhedral axis of the crystal in its cut form and perpendicular to the electric axis. It is this axis, therefore, that is called by the applicant the compressional axis.

In this case the electrodes 2 and 3 may be used either for applying alternating current potential of the desired frequency to vibrate the crystal at its resonant point or to receive the electric variations due to the compressional waves applied in the longitudinal axis *a* of the crystal. The crystal may be supported at its nodal position by the supports 4 and 5 and in order to broaden the resonance of the crystal itself, the ends of the crystal may be loaded or made of larger dimensions so as to produce the proper damping effect. Such a damping may be made to produce a receiving or transmitting structure having a resonance band of from 10,000 to 20,000 cycles in width and preferably extending between 20,000 to 40,000 cycles. The end plates 6 and 7 which may furnish the desired masses and radiating resistance may be supported or held at the end of the crystals in any suitable manner, as, for instance, by the tie rods 8 and 9.

In the structures shown in Figs. 2 and 3 in which the crystals may or may not be longitudinally resonant, the crystals are preferably mounted upon a base plate 10 which may be provided with grooves 11, 12, 13, 14, 15, 16 and 17 to receive the rows of crystals 18, 19, 20, 21, 22, 23, 24 and 25. At opposite ends of each row of crystals there are provided spring plates 26, 26 which not only

tend to hold the crystals in position, but also serve to take off or supply the electrical energy to the apparatus.

The spring plates are supported at the sides of the casing by means of the screws 27, 27. The base plate 10 and the side of the casing 28 may be made of the same piece of material and preferably is of some non-conductive hard material such as Bakelite, fiber or the like. Between successive crystals are placed electrodes 29, 29 and the crystals are so arranged that successive electrodes are positive and negative in the rows in the same manner as a connection for a series of batteries. In the arrangement set forth in Fig. 2 it will be noted that the two longest rows have 15 crystals each, the next rows 13, the next 9, and the smallest rows 5. In a parallel series combination the rows 21 and 20 are connected together as indicated by the connection 30 and this group to the plus and minus terminals 70, 71, respectively, by means of the leads 79 and 80. Likewise, the rows 22 and 23 are similarly connected together and to the energizing terminals by means of the leads 77 and 78. The rows 18, 19, 24 and 25 are series connected as illustrated. This circuit is traced as follows: the lead 76, crystal row 25, connector 82, lead 75, crystal row 24, connector 83, lead 81, crystal row 19, connector and lead 73, crystal row 18, lead 74, to the power supply. In this manner the apparatus may be connected in a series parallel combination in which there are three sets of 28 crystals in series. By varying the connections this, of course, may be altered and it is possible not only to connect all of the crystals in series, but it is also possible to connect all of the crystals in parallel.

A parallel connection of crystals is most advantageous with a circuit having a comparatively low input impedance. The series connection is preferable in a circuit having a high input impedance. The series connection in the present invention is preferably used when the crystals are directly connected in a grid circuit of a vacuum tube having a very high grid impedance and the parallel connection is preferably used in the present invention when the device is connected to an amplifier or vacuum tube receiving circuit through a transformer or impedance coupling.

In the structure shown in Fig. 3 the plate 10 is provided with a flange 31 through which the screws 32 pass threading into the casing 33. In this type of construction the entire crystal units may be removed by unscrewing the screws 32 and removing the plate 10 which comes out of the back of the casing after the cover 34, held to the casing by means of the screws 35, has been removed. The front open end of the casing may be covered by a soft rubber cover or diaphragm 36 which is preferably thin and acts primarily as a means of transmitting the compressional waves from the external medium to the crystals themselves. The diaphragm or cover 36 is held in place through the clamping flange 37 which is clamped between the side wall 28 of the plate 10 and the casing 33. Any other suitable method for clamping the diaphragm 36 may be used and in order thereby to remove the casing 28, it may be preferable to clamp the diaphragm 36 externally by means of a clamping ring which holds the diaphragm 36 to the casing 33. By cutting in the face of the casing 33 this clamping ring may be made flush with the surface of the casing so that no material protrudes beyond the continued surface of the vessel which is indicated by

the number 38, 38 just beyond the heavy clamping ring 39.

In the modification shown in Figs. 4 and 5 the casing 33 is provided with a rubber diaphragm 40 corresponding to the diaphragm 36, in Fig. 3. This diaphragm is held in position by means of the internal clamping ring 41 clamping the diaphragm to an inwardly extending flange in the casing 33.

The crystals 42, 42, as indicated more clearly in Fig. 4, are mounted radially about the center of the device upon a back plate 43 which is held to the casing 33 by means of the screws 44. As indicated in Fig. 5, at the center of the plate 43 is an inwardly extending boss 45 which may be made of the same piece as the plate 43 or may be made of a separate piece, as shown, and held to the plate 43 by means of the screws 46. The piece 45, as indicated in Fig. 4, has cut-out portions 47 in which the edges of the ends of the crystals are positioned. Similarly a ring 48 held to the plate 43 by means of the screws 49 is cut out at places 50 so that the crystals may be positioned by means of the inner piece 45 and the outer ring 48 to prevent them from sliding radially in the structure. The crystals are also held in position from side-way motion by means of the electrodes 51 and 52 which furnish a support at the sides of the crystal, as indicated in Fig. 5, as well as serving as the electrical connections for conducting the current to the crystal or acting as the receiving electrodes.

The cable 53 connecting the apparatus, as indicated in Fig. 5, comes through the center of the plate 54 through a stuffing box 55 to make the internal chamber of the apparatus watertight. The plate 54 is fastened to the casing 33 by means of the screws 55.

A tapped opening in the cover, closed by a plug 56, provides means whereby the interior of the casing may be filled with a liquid such as castor oil or other liquid substance in which the crystals will not dissolve, in which case it is not necessary to have the diaphragm 40 in contact with the ends of the crystals. Otherwise in order to have conduction to the external medium, the crystals should be in contact with the soft rubber cover. As has been previously mentioned, means may be provided in which the liquid within the casing may be put under the pressure corresponding to the external water pressure. However, merely filling the casing with a liquid has proved to be sufficient for ordinary purposes.

In the operation of the device the apparatus may be installed in the skin of a vessel or it may be used in sounding systems whereby it may be preferable to install it at the bottom of a vessel or have it so that it may be projected through a tube in the vessel itself. It is also possible to use this arrangement for direction finding and directional transmission in which case the oscillator shown in Figure 2 is used with its surface in a vertical or inclined position, and means are provided for rotating the device about a vertical axis to receive or transmit compressional waves in the desired direction. In order to use such an arrangement for projecting compressional wave beams downward, it is possible to provide the apparatus with a transverse or horizontal pivoted axis. This is easily accomplished by constructing the casing with two bearings at opposite ends of the diameter and pivotally supporting in a forked bearing the oscillator in this position. By means of an arm extending from the top part of the casing the surface of the oscillator may be inclined or tilted into the desired position.

When used as a directional receiver or transmitter in the range of 20,000 to 40,000 cycles it is preferable to make the active diaphragm area of the oscillator large and many times the wave length. For this purpose it is satisfactory to have the active surface of the oscillator of a diameter of approximately ten inches.

Having now described my invention, I claim:

1. An acoustical apparatus comprising in combination a housing provided with a face for the transit of acoustical energy, electromechanical interchanging means positioned within said housing, said means including a plurality of vibratory Rochelle salt crystals, each of which is provided with end surfaces perpendicular to its compressional axis, and means in said housing supporting said crystals at points on opposite side surfaces, said means maintaining said crystals in spaced-apart relation.

2. An acoustical apparatus comprising in combination a housing provided with a face for the transit of acoustical energy, electromechanical interchanging means positioned within said housing, said means including a plurality of vibratory Rochelle salt crystals, each of which is provided with end surfaces perpendicular to its compressional axis, a supporting element in said housing, and recesses in said supporting element shaped to conform with individual crystals, said crystals being disposed in said recesses to be thereby supported by said element at points on opposite side surfaces.

3. An acoustical apparatus comprising in combination a housing provided with a face for the transit of acoustical energy, electromechanical interchanging means positioned within said housing, said means including a plurality of vibratory Rochelle salt crystals, each of which is provided with end surfaces perpendicular to its compressional axis, a base plate in said housing for supporting said crystals, and raised portions on said base plate disposed between crystals for the spacing apart and lateral support thereof.

4. An acoustical apparatus comprising in combination a housing provided with a face for the transit of acoustical energy, electromechanical interchanging means positioned within said housing, said means including a plurality of vibratory Rochelle salt crystals, each of which is provided with end surfaces perpendicular to its compressional axis, a supporting element in said housing, said element contacting each crystal at a side surface, and raised portions on said supporting element contacting each crystal on other side surfaces.

5. An acoustical apparatus comprising in combination a housing provided with a face for the transit of acoustical energy, electromechanical interchanging means positioned within said housing, said means including a plurality of vibratory Rochelle salt crystals, each of which is provided with end surfaces perpendicular to its compressional axis, a pair of concentric circular supporting elements in said housing, said crystals being each radially disposed between said elements, said elements contacting said crystals at opposite side surfaces.

6. An acoustical apparatus comprising in combination a housing provided with a face for the transit of acoustical energy, electromechanical interchanging means positioned within said housing, said means including a plurality of vibratory Rochelle salt crystals, each of which is provided

with end surfaces perpendicular to its compressional axis, a pair of concentric circular supporting elements in said housing, said crystals being each radially disposed between said elements, said elements contacting said crystals at a first pair of opposite side surfaces, and radially-directed raised portions on said elements contacting and supporting said crystals against circumferential motion at a second pair of opposite side surfaces.

BEVERLY R. HUBBARD.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,450,246	Cady	Apr. 3, 1923
1,495,429	Nicolson	May 27, 1924
1,554,595	Perrin et al.	Sept. 22, 1925
1,578,296	Taylor	Apr. 20, 1926
1,581,701	Taylor	Apr. 20, 1926
1,655,625	Nicolson	Jan. 10, 1928
1,681,963	Williams	Aug. 28, 1928
1,717,263	Rice	June 11, 1929
1,737,019	Nicolson	Nov. 26, 1929
1,744,916	Nicolson	Jan. 28, 1930
1,766,042	Nicolson	June 24, 1930
1,803,274	Sawyer	Apr. 28, 1931
1,831,829	Thomas	Nov. 17, 1931
1,925,577	Tillyer	Sept. 5, 1933

FOREIGN PATENTS

Number	Country	Date
145,691	Great Britain	July 28, 1921
279,878	Great Britain	Mar. 8, 1928
339,596	Great Britain	Dec. 4, 1930