Aug. 22, 1961 A. V. GROSSE 2,997,006

CENTRIFUGAL REACTOR

Filed Oct. 23, 1953 2 Sheets-Sheet 1

Fig. 1.

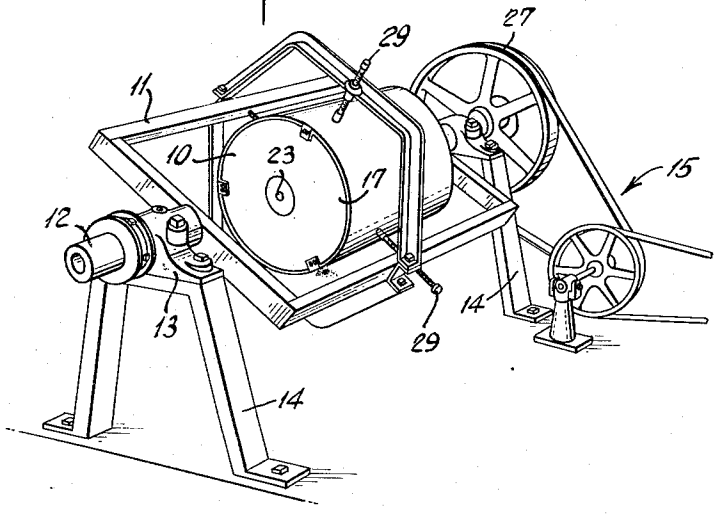
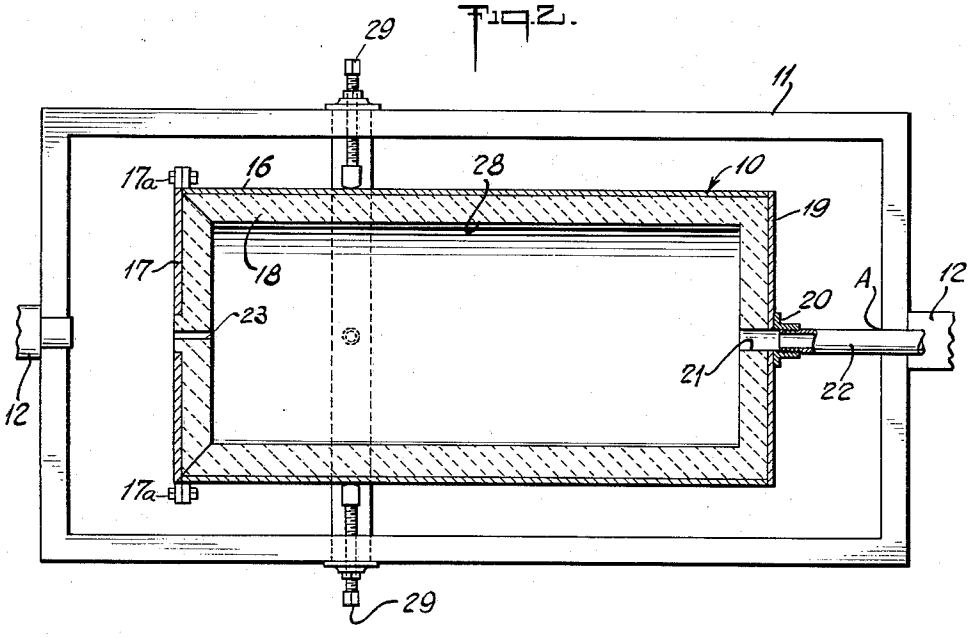


Fig. 2.



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Fig. 3.

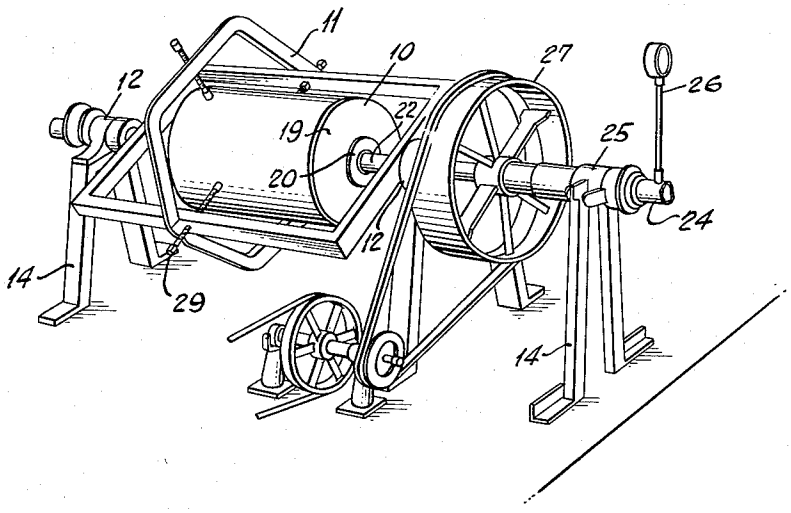
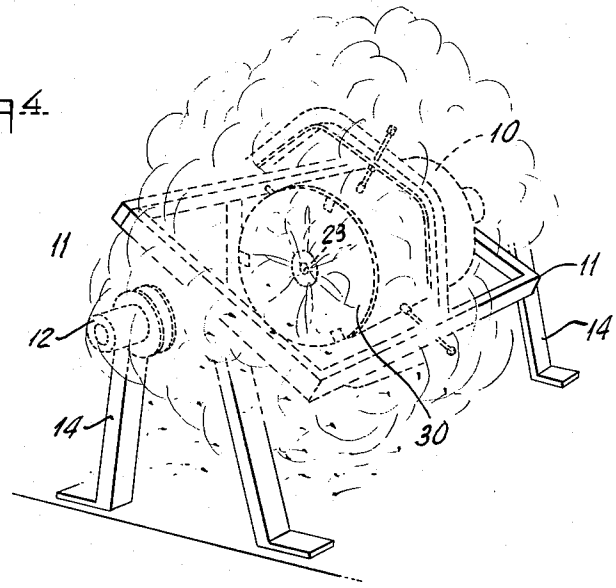


Fig. 4.



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CENTRIFUGAL REACTOR

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This invention relates to a furnace for the combustion of a highly exothermic metal and more particularly to a metal-burning furnace in which a boiling mass of highly exothermic metal is produced.

An object of this invention is to provide intense heat and produce very high temperatures by the combustion of a highly exothermic metal, such an aluminum, in a rotating furnace.

Another object of this invention is to provide a rotatable furnace having a circular internal wall of highly refractory material, for the combustion of a highly exothermic metal.

Another object of this invention is to produce a boiling mass of highly exothermic metal by rotation of a furnace on an axis.

Another object of the invention to provide a vapor of a highly exothermic metal by the combustion of the metal.

A further object of this invention is to discharge a brilliant cloud from the combustion of a highly exothermic metal in a rotating furnace.

These and other objects of this invention will become more apparent upon consideration of the following description taken together with the accompanying drawings, in which:

FIG. 1 is a perspective view of a furnace of this invention as seen from the discharge end;

FIG. 2 is an axial section of the barrel and frame of the furnace of this invention;

FIG. 3 is a perspective view of the furnace as seen from the feed end; and

FIG. 4 is a perspective view of the furnace as seen from the discharge end while rotating and operating.

In general this invention provides a rotatable furnace chamber having means for feeding reactants into a combustion chamber in which extremely high temperatures and high calorie production are achievable. The combustion chamber wall assists in the achievement of the extremely high temperature and calorie production by preventing the too rapid dissipation of heat through the chamber wall.

One highly exothermic metal employable in this invention is aluminum. Aluminum is a readily oxidizable metal which melts at 660° C. When oxygen and aluminum are introduced into an area of high heat the aluminum melts, vaporizes and burns in the manner of this invention. This combustion generates heat at a temperature at least above 1500° C. and at full operating conditions at a very high temperature of above 3000° C. Additional aluminum introduced into such a combustion chamber is heated to boiling by continued combustion. In this invention this boiling liquid aluminum is spread over the internal surface of the furnace of this invention by rotating the furnace on an axis during the combustion. The spread liquid boiling aluminum lies over the refractory lining of the rotating furnace and is kept boiling at a temperature of about 2300° C. by additional reactant material fed into the combustion area. A gaseous mixture of vaporized aluminum and oxygen adjacent the boiling aluminum sustains the combustion which generates extreme heat.

The rate of combustion is dependent upon the rate of feed of both aluminum and oxygen and the rapid mixing of aluminum and oxygen. The burning, boiling mass of aluminum metal is brilliant, producing aluminum vapors which are forced out of the reactor through an escape port, if the oxygen feed is cut below the stoichiometric point.

According to this invention a highly exothermic metal, such as aluminum, is burned in a refractory-lined confined space at a high rate of combustion to achieve an extremely high rate of caloric production per unit of volume of the confined space. The refractory-lined confined space is rotated to increase the combustion area and thereby increase and concentrate the caloric production.

The refractory walls of the confined space, which form a chamber for the combustion of the highly exothermic metal in accordance with this invention, must serve to contain the heat of combustion, irrespective of the degree of temperature and prevent dissipation of the heat. It is preferable that the wall is not easily dissociable. Additionally, the wall structure and the combustion reaction must cooperate to tend to preserve a wall structure which prevents the dissipation of heat, as described below in further detail.

In my Patent No. 2,764,109 issued on September 25, 1956, two other factors essential to this invention are also described. It is necessary to the attainment of the heat and calorie production of this invention that the volume of the combustion chamber formed by the confined space and the rate of feed of the reactants be associated so as to produce a building-up of the heat of combustion. The rate of feed must be rapid in relation to the volume of the combustion chamber so as to provide adequate quantities of reactants per unit of time so as to produce the novel condition.

In addition to these above-mentioned essential factors this invention provides a rotation of the combustion chamber which increases the concentration of the reaction and increases the reaction surface in relation to the volume of the combustion chamber.

The limiting factor of this invention is the dissociation temperature of the refractory material which lines the reaction area. This may be a prepared lining or oxide product from the combustion reaction. The boiling metal cools the lining at the areas of contact.

The apparatus of this invention, in general terms, is a barrel having a lining of a few inches of refractory material and being mounted so as to be rotatable on its axis. The barrel has a chamber with at least two ports, a feed port and an escape port. The combustion reactants are fed into the chamber through suitable feed devices connected with a stuffing box.

Referring specifically to the drawing, FIG. 1 shows an embodiment of the apparatus of this invention comprising a cylindrical furnace 10 and a rotatably mounted frame 11. The frame 11 has arbors 12 turning in journals 13 and is thereby supported on stands 14 at its respective ends. A drive mechanism 15 is made up of a combination of belts and pulley wheels.

A sectional view of the furnace 10 and frame 11 is shown in FIG. 2. The furnace 10 has a cylindrical shell 16. A removable end plate 17 is attached to the left end of the shell 16. A removable refractory lining 18 covers the inner surface of the cylindrical shell 16. At the right end of the cylindrical shell 16, FIG. 2, an end plate 19 may be permanent. The end plate 19 has brazed at the center of its outer surface a floor flange 20. This flange 20 is centered over a port 21 extending through the end plate 19 and the lining 18 on the end plate 19. A nipple 22 is screwed into the flange 20 and extends to and is fixed in the frame 11 at A. An escape port 23 is provided at the center of the removable and plate 17.

The oxygen and aluminum are fed into the furnace 10 through the nipple 22 and port 21 from a feed pipe 24 through a stuffing box 25 into which both the pipe 24

and nipple 22 extend as shown in FIG. 3. A gauge 26 on the pipe 24 registers the pressure of the oxygen in the feed.

A pulley wheel 27 is mounted on the arbor 12 shown at the right end of the apparatus. The right end arbor passing through the right end journal 13 is joined with the frame 11 at the right end as shown in FIGS. 2 and 3. The frame 11 and the furnace 10 are driven from the drive mechanism 15 through the pulley wheel 27 and the right end arbor 12.

The furnace 10 is prepared for a combustion reaction by inserting the lining 18 which has a thickness of the order of two inches. The cylindrical shell 16 may be of any size and the operation of this invention has been successful with shells ranging from nine to twenty-four inches in length and six to eighteen inches in diameter. Larger sizes and greater length to diameter ratios may be used. The larger the size the easier the control and smoothness of operation, if the apparatus is properly designed. The feed port 21 forms a one inch passage through lining 18 while the escape port 23 forms a one-half inch passage. The lining 18 is first fixed on the cylindrical portion and permanent plate 19 and then the removable plate 17 with the lining on it is fastened in position by fastening means 17*a* on the plate 17 and shell 16. A chamber 28 is formed by the lining 18. The chamber 28 is then charged with about 300 grams of aluminum shavings and 300 grams of aluminum powder. The cylindrical furnace 10 is then held and centered in the rotating frame 11 by means of four adjustable bolts 29. With the furnace 10 in place the combustion is started by placing a lighted cigarette in the chamber 28 and then allowing oxygen to flow into the combustion space. After the combustion begins it is propagated by feeding aluminum in the form of one-eighth inch rods into the chamber. These rods are fed through the escape port 23 in the removable end plate 17. Rotation of the reactor is not begun until the combustion progresses rapidly or until a burning pool of liquid aluminum is formed within the reactor. This is also referred to as a sun. This usually requires 5 to 10 minutes. The combustion of the liquid aluminum is maintained by the rate of feed of the reactants and when this combustion reaches a steady state condition, the drive mechanism 15 is started and the furnace 10 is rotated at 300 r.p.m.

Once the furnace 10 is set in motion it is fed with aluminum rods and oxygen through the stuffing box 25 and rotating seal arrangement attached to the rotating frame. The aluminum rods and oxygen feed through the pipe 24 and into the rotating device through the nipple 22 attached to the frame 11 of the rotating device and through the flange 20.

When in operation, combustion takes place very rapidly and the interior of the furnace is completely covered with a sun. This results in tremendous quantities of heat being generated and causes vaporization of aluminum, if no excess of oxygen is used. This vaporized aluminum is emitted from the escape port 23 of the rotating furnace 10 and burns in air with a brilliant flame 30 which resembles a ball of fire, as indicated in FIG. 4. This flame 30 represents and illustrates a fine constricted high velocity jet of burning aluminum as it emerges from port 23.

Typical oxygen rates vary from 65 to 500 liters per minute and the aluminum consumption is over 20 pounds per run. If an excess of oxygen is used in the combustion the aluminum is completely oxidized within the chamber 28. The aluminum may be fed either in the form of a rod, a wire or powder. Oxygen is fed at varying rates and pressures determined by the demand of the desired rate of combustion.

On starting the process the initial aluminum burns and melts as it burns to form globules which are continuously enlarged into a continuous single, molten, burning mass of boiling aluminum. Upon rotation of the furnace 10 this continuous mass of molten aluminum spreads to cover the entire inner surface of the lining 18. The reaction is continued by a continuous feeding of aluminum and oxygen so as to maintain the sun of burning, boiling aluminum spread over the lining 18 surface. This reaction produces in the sun of the chamber 28 aluminum vapor formed by the build-up of heat resulting from the continuation of the burning reaction and the conservation of heat within the cylindrical furnace 10. This build-up of heat and aluminum vapor continues until the flame 30 issues from the escape port 23, as shown in FIG. 4. Upon continuation of the feed of oxygen and aluminum, the flame 30 is maintained and exceedingly high release of energy is obtained.

The rate of burning of the boiling aluminum has been found to be four grams of aluminum per minute per square centimeter of boiling aluminum surface with a stationary aluminum pool. This rate can be increased by distributing this surface and causing turbulence. The calorie production and heat release can be accurately determined from the quantity of aluminum and oxygen consumption. The complete combustion of aluminum to aluminum oxide follows the equation:

$$2Al 1\tfrac{1}{2} O_2 Al_2O_3$$

In this complete combustion 1 gram of aluminum metal consumes 0.68 liter of pure oxygen gas at 25° C. and 1 atmosphere. The heat of combustion of aluminum is 7410 calories per gram or 13,350 B.t.u. per pound. If one pound of aluminum is burned per minute it will consume 309 liters of oxygen and generate 13,350 B.t.u. per minute or 3,360,000 calories per minute. Similar releases of energy and production of heat can be obtained in other centrifugal reactors with properly adjusted rates of reactant feed and aluminum combustion. Also similar releases are obtainable with other exothermic metals.

Thus, this invention produces the burning of a highly exothermic metal in a confined space having a refractory wall. The high heat energy production and release of this invention is obtained by feeding the reactant aluminum and oxygen into the confined space at a rate which in the volume of the confined space provides an extremely high caloric production per unit of volume and by rotating the confined space to increase the surface area of combustion. In addition, a jet of burning aluminum vapor is produced and issues from the rotating furnace. The general advantage of the centrifugal reactor furnace over stationary reactor furnaces is that the burning, boiling aluminum sun can be extended over the whole inner surface of the hollow cylndrical chamber and the rate of combustion and its consequent heat energy production is substantially increased.

Various modifications of the embodiment of this invention described herein may be made within the spirit thereof. For example, aluminum metal has been disclosed as a fuel in this invention as it is a practical material for consumption in the combustion reaction. It will be understood, however, that other substances may be suitably employed in the operation of the invention. For example, such other metals beryllium, zirconium, titanium, lanthanum, cerium and other rare earths are possible in this invention with results similar to the above described operation with aluminum. In each case, it is preferred but not limited that the furnace lining be composed of the respective oxide product. Mixtures of these metals may be used. Also noncombustible or less combustible metals may be added to produce vapor jets of mixed composition. For example if copper or silver is added, they will boil out with the aluminum because at the high temperature they can only exist as free metals and not as oxides. Another modification can be found in the combustion of aluminum in a device of this invention under pressure or under decreased pressure. The limit to the temperature attained by the reaction is the

dissociation point of the product of combustion. The dissociation point in turn is influenced by total pressure. If the pressure is increased so may the ultimate temperature attained by the apparatus be increased.

The centrifugal reactor furnace may be modified to rotate on a vertcial axis. This furnace may also be water-jacketed to cool the refractory lining and postpone the dissociation thereof. Other cooling media may also be used.

If an excess of oxygen is supplied it will come out unused through the exit port; such excess may be used to carry the extremely hot vapors of aluminum oxide out of the chamber **28** if desired. At high rates of combustion the aluminum oxide vapors will boil out through the exit port by themselves. On the other hand if the amount of oxygen is cut down below the stoichiometric ratio, or even cut out altogether for a short time, metallic aluminum vapors will boil out of the exit port **23**. This boiling will continue as long as the temperature and heat content of the apparatus are above the boiling point of aluminum. The boiling point is about 2300° at 1.0 atm. pressure; the heat of vaporization of aluminum at the boiling point is 2520 calories per gram. Thus the combustion of 1 lb. of aluminum will generate sufficient heat to boil off nearly 3 lb .of the metal, assuming no heat loss. By the proper balance of combustion and boiling the aluminum can be boiled out of the centrifugal reactor at a continuous rate. The aluminum vapors burn from the exit port with a yellow flame, quite different in appearance from the dazzling white cloud of aluminum oxide. Thus from the appearance of the flame alone, just like in the familiar case of a gas burner, one can judge whether an excess of aluminum or oxygen is used in the combustion.

If instead of admitting the aluminum vapors into the air, they are collected in an inert gas such as argon, helium or in a vacuum, no subsequent oxidation of the vapors will take place and the aluminum may be condensed to a dust or a liquid. This process may be used for coating purposes of various objects placed in the path of the vapors. An enclosed cylinder may be tightly placed on the exhaust port or the whole reactor may be placed in a larger chamber. The enclosed cylinder or the larger chamber contains the inert gas or the vacuum. The following example is illustrative of the release of heat and the boiling of aluminum brought about by burning aluminum in a device of this invention and is not to be considered limitative.

Example

The hollow cylindrical furnace was one foot long and four inches in diameter and had a liner of alumina providing a surface area of 150 square inches or 970 square centimeters and a volume of 150 cubic inches or 2.46 liters. Aluminum and oxygen were fed into the cylindrical furnace and burned at a fast rate. The oxygen was fed at the rate of 300 liters per minute and the aluminum fed and burned at a rate of 400 grams per minute or 0.88 pound per minute. This reaction generated 2,964,000 calories per minute or 11,750 B.t.u. per minute. The heat loading factor was 1,365,000 calories per minute and per liter of reaction space. It should be recognized that these heat loading factors are very high. Previously combustion chambers have normally produced 11,000 calories per liter per minute or 50,000 calories per minute per liter for some oil burners.

Under these conditions and at the fast rate of combustion, a substantial quantity of alumina boils out through the exit port as a dazzling white cloud or ball of fire. If, after steady conditions have been reached, the oxygen feed is cut down to 100 liters a minute unburned metallic aluminum boils out of the port and burns in air as described previously, with a characteristic yellow flame.

This application is a continuation in part of my co-pending application Serial Number 260,424, filed December 7, 1953.

The device of this invention can be used to produce extremely high temperatures and to produce a flame which burns at a high temperature. It will be apparent that the above described embodiments are for the purpose of illustration only and that various modifications to these embodiments of this description may be made without departing from the spirit of this invention. For example, the rates of feed of aluminum and oxygen may be varied for any given combustion chamber and various sizes of combustion chambers may be used. It is therefore intended that the scope of this invention be limited only by the appended claims.

I claim:

1. A method of producing large quantities of heat at high temperatures within an unobstructed confined space formed by end walls having restricted openings in each wall and a generally cylindrical refractory wall comprising rotating said walls at a high speed, continuously introducing solid highly exothermic metal and oxygen into said space, while the walls are rotating, melting said highly exothermic metal to form a molten mass, evenly distributing the molten mass completely around said walls by the rotation thereof to line the entire wall with the molten highly exothermic metal and to form a continuous molten surface of distributed highly exothermic metal surrounding said space, vigorously vaporizing said evenly distributed highly exothermic metal over the entire distributed surface of said mass to feed said unobstructed confined space with highly exothermic metal vapor, combining said vaporous highly exothermic metal with the oxygen within said confined space, retaining at least a portion of the heat of combustion within the confined space to raise the temperature of subsequent oxidation to produce large quantities of heat at a temperature above 1500° C. and at a superatmospheric pressure and exhausting the products of combustion from said space in a fine constricted high velocity jet.

2. A method of producing large quantities of heat at high temperatures within a confined space formed by end walls having restricted openings in each wall and a generally cylindrical refractory wall comprising rotating said walls at a high speed, continuously introducing solid highly exothermic metal and oxygen into said space while the walls are rotating, melting said highly exothermic metal to form a molten mass, evenly distributing the molten mass completely around said walls by the rotation thereof to line the entire wall with the molten highly exothermic metal and to form a continuous molten surface of distributed highly exothermic metal surrounding said space, vigorously vaporizing said highly exothermic metal over the entire distributed surface of said mass to feed said confined space with highly exothermic metal vapor, combining a portion of said vaporous highly exothermic metal with the oxygen within said confined space, retaining at least a portion of the heat of combustion within the confined space to raise the temperature of subsequent oxidation to produce large quantities of heat at a temperature above 1500° C. and a superatmospheric pressure and exhausting the products of combustion and the remainder of the metal vapor in a fine constricted high velocity jet.

3. A method of producing large quantities of heat at high temperatures within a confined space formed by end walls having a restricted opening in each wall and a generally cylindrical refractory wall comprising rotating said walls at a high speed, continuously introducing solid aluminum and oxygen into said space while the walls are rotating, melting said aluminum to form a molten mass, evenly distributing the molten mass completely around said walls to line the entire wall with the molten

aluminum and to form a continuous molten surface of distributed aluminum surrounding said space, vigorously vaporizing said evenly distributed aluminum over the entire distributed surface of said mass to feed said confined space with aluminum vapor, combining said vaporous aluminum with the oxygen within said confined space, retaining at least a portion of the heat of combustion within the confined space to raise the temperature of subsequent oxidation to produce large quantities of heat at a temperature above 1500° C. and at a superatmospheric pressure and exhausting the aluminum oxide from said space in a fine constricted high velocity jet.

4. A method of producing large quantities of heat at high temperatures as set forth in claim 1 wherein said highly exothermic metal is of the class comprising aluminum, beryllium, zirconium, titanium, lanthanum and cerium.

References Cited in the file of this patent

UNITED STATES PATENTS

1,079,151	Smallwood	Nov. 18, 1913
1,506,322	O'Neill	Aug. 26, 1924
1,506,323	O'Neill	Aug. 26, 1924
1,532,930	O'Neill	Apr. 7, 1925
1,980,263	Frost	Nov. 13, 1934
2,273,707	Heath	Feb. 17, 1942
2,289,682	Rasor	July 14, 1942
2,430,101	Campbell	Nov. 7, 1947
2,454,733	Dahl	Nov. 23, 1948
2,535,316	Ohlsson	Dec. 26, 1950

FOREIGN PATENTS

323,866	Great Britain	Jan. 16, 1930
372,429	Great Britain	May 12, 1932