Oct. 22, 1963 H. A. TOULMIN, JR 3,107,485

PROPULSION MEANS AND METHOD FOR SPACE EMPLOYING A VOLATILE ALKENE AND METAL CARBONYL VEHICLES

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Fig. 1

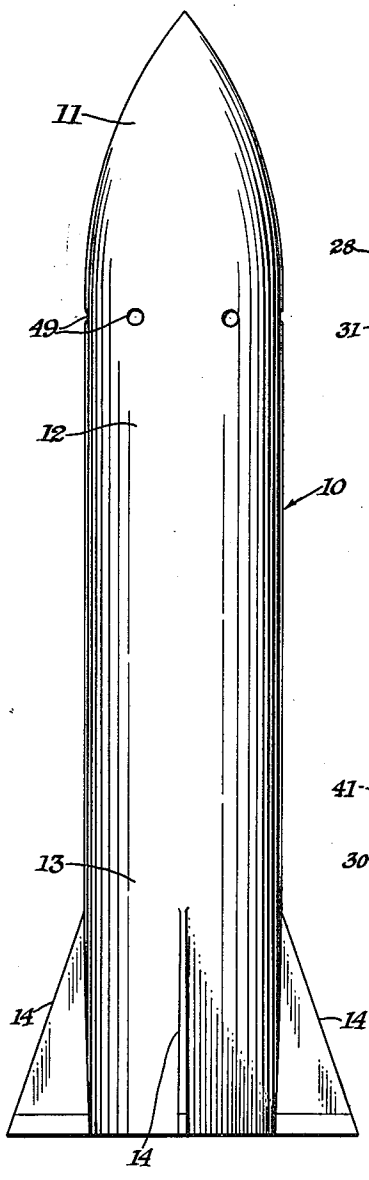


Fig. 3

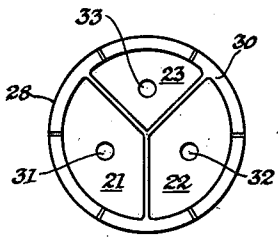


Fig. 4

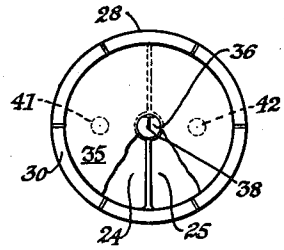
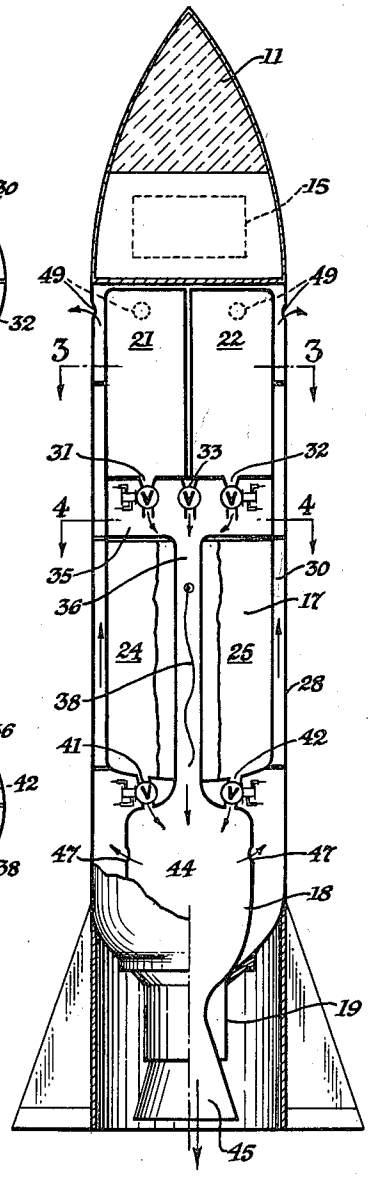


Fig. 2



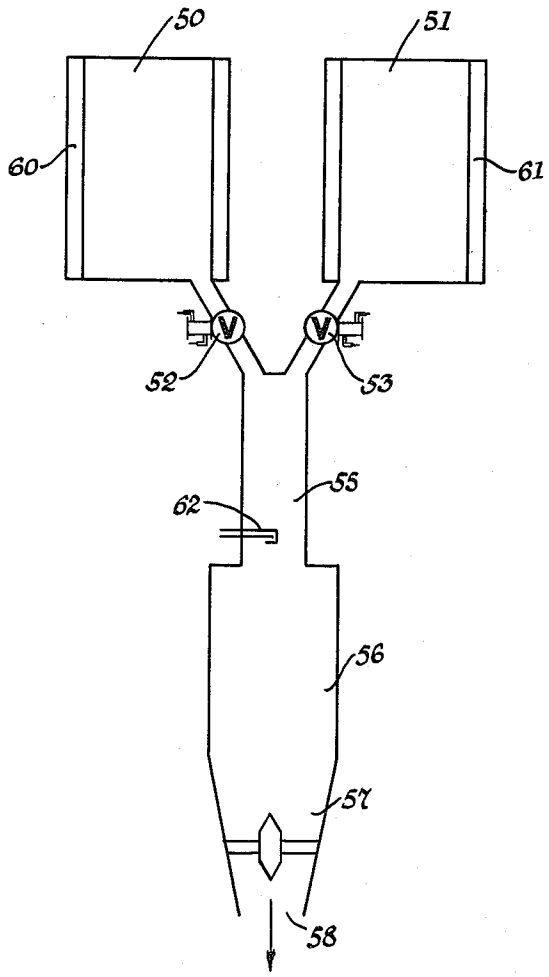
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Fig. 5



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PROPULSION MEANS AND METHOD FOR SPACE VEHICLES EMPLOYING A VOLATILE ALKENE AND METAL CARBONYL

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This invention relates to missiles and rockets, and more particularly to improved missiles or rockets useful for space flight, and which are propelled by catalyzed combustible gases.

It is one of the objects of the invention to provide a missile or rocket of the character described which is propelled by a gaseous fuel operated motor and which eliminates the disadvantages encountered in the use of propellants such as solid and liquid fuels.

Another object of the invention is to provide a high energy fuel for operating missiles, rockets and space ships and which is efficient in operation.

The invention overcomes the difficulties heretofore encountered in fuels utilized for jet propulsion and which are of the solid and liquid type, with their attendant danger of explosion.

The present invention provides an improved gaseous propelled missile or rocket which is propelled by blending carbon monoxide, oxygen, nitrogen, hydrogen, colloidal metal particles and hydrocarbon gases.

The invention provides a missile which accomplishes the blending together of the gaseous constituents in proportions such that a substantially self-combustible fuel is produced. The gaseous fuel is catalyzed by blending gaseous heat-decomposable metal compounds with hydrocarbon and oxygen to release high energy propellant gases at high temperature.

In accordance with applicant's invention, the gaseous propellant preferably comprises a blend of gaseous metal carbonyl and hydrocarbon gas such as propylene to which is admixed nitrogen, oxygen, and hydrogen as may be formed as a decomposition product. During combustion the gaseous metal carbonyl decomposes to release in situ the metal particles which catalyze the combustion to produce a high heat energy flame.

The invention may be better understood from the following detailed description, taken in conjunction with the drawings, in which:

FIGURE 1 is an elevational view of a missile powered with gaseous propellant in accordance with the invention;

FIGURE 2 shows a similar view in elevation of the missile or rocket with parts of the same broken away to illustrate the tank compartments holding the propellant gases and interconnected combustion chamber for jet propelling the missile;

FIGURE 3 is a view in cross-section taken on the line 3—3 and looking in the direction of the arrows;

FIGURE 4 is a similar view in cross-section and looking in the direction of the arrows;

FIGURE 5 shows a modification, and wherein the motor for driving the rocket or space vehicle is illustrated and the blending of the gases to provide the propellant jet thrust is shown schematically.

Referring to the drawings in more detail, particularly to FIGURES 1 and 2, a missile 10, as illustrated in FIGURE 1 comprises a warhead or payload section 11, body or fuel portion 12, and tail section 13, the latter being provided with vanes 14.

The interior construction of the missile, as illustrated in FIGURE 2, comprises a guidance control and instrument section 15, multiple fuel tank section, generally indicated at 16 and 17, and a main combustion chamber 18 with an inter-communicating nozzle exhaust section generally indicated at 19. Fuel tanks 21, 22, 23, 24 and 25 are fixedly positioned in the fuel section and are of less diameter than the outer casing 28 of the missile and defining a jacket or space 30 for the flow of hot exhaust gases to maintain the fuel tanks heated during operation and flight of the missile.

Tank 21 is filled with a gaseous metal carbonyl or the like heat-decomposable gaseous metal compound, which is thermally decomposable such as nickel carbonyl, whereas tank 22 is filled with an olefin gas for example acetylene, propylene or the like, and tank 23 is filled with nitrogen. Control of the gases flowing from the fuel tanks 21, 22 and 23 is maintained by the electro-magnetic valves 31, 32 and 33 respectively. A controlled blend of the fuel gases from tanks 21, 22 and 23 is mixed in the auxiliary chamber 35 which communicates with a central tubular opening 36 between tanks 24 and 25, and forming the first stage combustion chamber. This first stage combustion chamber is provided with an igniter means 38 for igniting the gaseous mixture which, as shown in FIGURE 2, may consist of an electrically heated wire, and such may be made of nichrome or the like heat-resistant material.

Arranged about the central first-stage combustion chamber 36 are the oxygen tanks 24 and 25 which communicate through electro-magnetic valves 41 and 42, respectively, with the main combustion chamber 44. The fuel tanks are preferably connected to the electro-magnetic valves through suitable constant pressure valves, not shown, whereby controlled introduction of the gases to the combustion chamber is maintained. High temperature exhaust gases from the combustion chamber 44 exit through the exhaust nozzle 45 and exert the jet thrust for propelling the missile.

An important feature of the missile comprising the utilization of a portion of the hot exhaust gases to preheat the fuel tanks. This is provided for by the auxiliary exhaust ports 47 which are arranged circumferentially about the upper portion of the combustion chamber 44 and permit hot exhaust gases to enter the jacket space portion 48 and circulate upward through the annular space 30 and about the fuel tanks, as indicated by the arrows in FIGURE 2, and exiting through the exhaust ports 49, a plurality of which are arranged circumferentially about the casing 28 of the missile.

Another important feature of the invention is the provision for forming a metal catalyst in situ upon admixing and burning of the fuel mixture. This is accomplished by introducing a thermally decomposable gaseous metal compound into the oxygen and olefin gaseous fuel mixture. While, as illustrated, the gaseous metal compound is stored in a separate tank, if desired, the same may be pre-mixed with the gaseous olefin. The release of metal particles in situ which are of submicron fineness and nascent metal functions to enhance the combustion and is

believed to assist in producing the high temperature, such as in the region of 2000 to 3500° K.

In operation of the missile illustrated in FIGURES 1 through 4, controlled amounts of the fuel gas mixture from tanks **21**, **22** and **23** are blended and ignited in the first stage combustion chamber **35** and thence into the main combustion chamber **44** where oxygen is introduced into the metal catalyzed burning mixture from the first stage. A useful fuel mixture for admixing and ignition in the first stage combustion chamber to which oxygen is added and burned in the main combustion chamber consists, by volume, of propylene gas mixed with 25 to 35% nickel carbonyl gas and 20 to 30% nitrogen. To this ignited mixture is introduced approximately one-third by volume of oxygen. Decomposition of the gaseous metal compound introduces the colloidal particles of nickel which catalyzes the oxidation and the metal particles released burn to increase the temperature and volume of gases thus enhancing the thrust jet force.

The invention utilizes the high energy developed from burning gases comprising CO—O_2 and which gases are blended with hydrocarbon, particularly the olefins and oxygen, to provide a metal catalyzed combustible mixture, and which mixture burns at a high temperature to provide a high thrust for propelling the missile or rocket.

The high temperatures developed by flames of CO—O_2 mixtures with hydrocarbon is described in the publication of the National Bureau of Standards, Circular 523, March 10, 1954, entitled "Energy Pressure in Hot Gases." The high energy distribution in flames of CO—O_2 and hydrocarbons is shown below.

TABLE I

Gas Mixture	Temperature Calculated, °K. (C+273.1=K.°)
6 CO+1.5 O_2	2,850.
6 CO+1.5 O_2+1.3 CO_2	2,625.
2 O_2+C_2H_6	Above 3,000.
2 O_2+N_2	3,000.
2 C_2H_2+2H_2	3,200.

In the above table it will be readily seen that mixtures or blends of hydrocarbon gases and oxygen and nitrogen produce high temperature burning flames which when catalyzed by the metal particles formed in situ by the heat-decomposable gaseous metal compound, produce a large volume of high temperature propellant gases.

A portion of the hot gases which burn in the second stage combustion chamber **44** are exhausted through the jacket portion **30** and maintain the storage fuel tanks heated, as described. The gases from the jacket space **30** are allowed to exhaust or are expelled through the port openings **49** as aforementioned.

The electro-magnetic valves are electrically controlled so as to introduce the proportionate amount of gases desired to the combustion chambers. During the initial stage, metal particles are released upon heat-decomposition of the metal carbonyl to provide carbon monoxide and colloidal catalytic metal particles. The metal particles thus catalyze the combustion and increase the temperature of burning of the gases.

In FIGURE 5 a space vehicle gas power plant is schematically illustrated, and wherein the same comprises a metal carbonyl storage tank **50** and an olefin storage gas tank **51** which are connected through electro-magnetic valves **52** and **53** respectively, with a mixing and ignition chamber **55**, the latter communicating with a combustion chamber **56**. Combustion chamber **56** is connected to a venturi jet exhaust nozzle section **57** and from which the hot gases are exhausted at **58**, as indicated by the arrows.

In the power plant modification illustrated in FIGURE 5, operation of the valves **52** and **53** is made responsive to the pressure of the atmosphere; suitable pressure responsive means being connected to the electrically operated mechanism for operating the valves, whereby as the atmospheric pressure decreases the valves are automatically regulated so that less fuel is supplied to the combustion chamber. In this manner the fuel is conserved and the missile made to travel further than otherwise would be possible.

The following table shows the approximate variation in atmospheric pressure over a range of 20 miles from the earth.

TABLE II

Distance in miles	Pressure	
	lbs./sq. in.	Inches of Hg
At sea level	14.7	29.9
2	10.1	20.5
4	6.7	13.7
6	4.3	8.8
8	2.7	5.5
10	1.6	3.4
12	1.0	2.0
14	0.6	1.2
16	0.4	0.8
18	0.1	0.3
20	0.05	0.1

In the operation of the missile or rocket, where the fuel fed to the combustion chamber is controlled or regulated in accordance with the atmospheric pressure, as described, valves **52** and **53** will be operated to feed the maximum fuel at sea level and then taper off after the missile reaches the height of its trajectory, the fuel valves being restricted to feed just enough fuel to propel the missile or rocket horizontally to its designated target. In this manner, a missile may be driven over a calculated range to a target utilizing the fuel more efficiently.

In the plant illustrated in FIGURE 5, the tanks **50** and **51** are provided with heating jackets **60** and **61**. Heat is supplied to preheat the gaseous fuel in the tanks, preferably by exhaust gases, however, if desired, suitable electrical heating means may be used for this purpose.

Means are provided such as electrically heated wire **62** in the chamber **55** for igniting the fuel mixture which is then passed into the main combustion chamber **56** wherein the fuel is burned and exhausted through the nozzle **57** to provide the thrust.

The spaced vehicle, as illustrated, is propelled by the burning of two gases blended to release catalytic metal particles as in the missile power plant or motor illustrated in FIGURES 1 and 2.

Where desired, a certain amount of liquid or solid fuel may be introduced into the second stage combustion chamber to increase the volume of hot gases released.

As the metal carbonyl gas there may be used various heat-decomposable gaseous metal carbonyl compounds of nickel, chromium, titanium, molybdenum, cobalt and the like.

Metals may be introduced as gaseous metal carbonyls or vaporized solutions of certain of the metal carbonyls in readily vaporizable solvents (for example petroleum ether) also nitroxyl compounds, nitrosyl carbonyls, metal hydrides, metal alkyls, metal halides, and the like.

Illustrative compounds of the light metals, e.g., aluminum, magnesium, tin and zinc are the alkyl or aryls such as aluminum triethyl, magnesium trimethyl and the corresponding triphenyls, and organo tin and zinc compounds which are volatile and thermally decomposable.

Illustrative compounds of other groups are the nitroxyls, such as copper nitroxyl; nitrosyl carbonyls, for example, cobalt nitrosyl carbonyl; hydrides, such as antimony hydride, tin hydride; metal alkyls, or aryls such as chromyl chloride; and carbonyl halogens, for example, osmium carbonyl bromide, ruthenium carbonyl chloride, and the like.

Each material from which a metal may be released has a temperature at which decomposition is complete. However, decomposition may take place slowly at a lower temperature or while the vapors are being raised in tem-

perature through some particular range. Where the temperature at which the gaseous metal compound employed decomposes at temperatures below about 400° F. the tank is provided with a heat-insulating jacket, such as may be made of glass wool. The tank thus heat insulated is prevented from becoming over-heated and such as to cause premature decomposition of the gaseous metal compound.

As the olefin gas to be mixed with the heat-decomposable gaseous metal compound there is preferably employed the alkenes, for example ethylene, propylene and the like, which are gases at ordinary temperature or substantially at room temperature, and may be stored at relatively high temperatures and pressures.

The following table shows the melting point and boiling point of the alkenes which are useful for the purpose of this invention.

TABLE III

Name	Formula	Carbon Structure	M.P., ° C.	B.P., ° C.
Ethylene	C_2H_4	C=C	−169.4	−102.4
Propylene	C_3H_6	C.C.=C	−185	−47.7
Butene-1	C_4H_8	C.C.C.=C		−6.5
Butene-2 (cis)	C_4H_8	C.C=C.C.	−139.3	−3.7
Isobutylene	C_4H_8	C.C.=C · C	−140.7	−6.6
Pentene-1	C_5H_{10}	C.C.C.C=C		−30.1
2-Methylbutene-1	C_5H_{10}	C.C.C.=C · C		−31.0
3-Methylbutene-1	C_5H_{10}	C.C.C.=C · C		−20.1

As will be seen from the table, the physical constants of the alkenes, which are used to blend with the gaseous metal compounds have relatively low boiling points and can be burned when mixed with oxygen or carbon monoxide.

Hydrocarbons such as olefins are employed upon combustion provide many free radical reactions. The oxidation of hydrocarbons in the vapor phase is different than that which takes place in the presence of catalysts. With the use of a catalyst as is employed by the present invention, the hydrocarbons may be oxidized at somewhat lower temperatures so that the combustion can be readily maintained. Methane, for example, is oxidized at rather high temperature above 500° C. in the absence of catalyst. With the catalyst it can be oxidized at lower temperatures. The reactions involved upon oxidizing methane, for example are illustrated below—

TABLE IV

$$CH_3+O_2\rightarrow HCHO+OH$$
$$HCHO+O_2\rightarrow \text{Free radicals OH}$$
$$CH_4+OH\rightarrow CH_3+H_2O$$
$$CH_3+O_2\rightarrow HCHO+OH$$
$$OH+HCHO\rightarrow H_2O+CHO$$
$$HCHO+O_2\rightarrow HCHO$$

As will be seen from the oxidation of methane free radicals (OH) are liberated and which unite with further gas to complete the oxidation.

Further, the following table shows the heat of combustion and cubic feet of oxygen required per cubic foot of a number of gaseous hydrocarbons for combustion of the same.

TABLE V

Name of Gas	Heat of Combustion, Kilogram Calories	Cubic Feet oxygen required per cubic foot gas
Methane	210.8	2.0
Ethane	368.4	3.5
Propane	526.3	5.0
Isobutane	683.4	6.5
Pentane	838.3	

As will be noted from the above table, as the number of carbon-hydron radicals increase the heat of combustion increases and as well as the oxygen required for burning the same.

In the burning of hydrocarbons with oxygen, the total heat given off in burning C_6H_6 is approximately 1500 calories. This may be represented by the equation—

$$2C_6H_6+150_2CH_2O+12CO_2$$

Where 24 calories represents the heat released by the C and H of the benzene molecule. Thus fuels rich in H_2 will produce high jet velocities and which is further enhanced by the presence of collodial catalytic metal particles.

The concentration of the gaseous fuel mixture will be varied depending upon the temperature of operation desired and may be maintained either below or above explosive limits. In the practice of the invention it is desired to maintain the gases below their explosive limits since concentration of gases above these limits results in heat release so great and so rapid that reasonable temperatures cannot be maintained in the combustion chamber and may result in damage to the space vehicle or missile being propelled.

It is important to preheat the gases so that the operation can be carried out at temperatures in the feed mixture of 350–700° C. In the second stage combustion chamber it is desired that within one-quarter to two seconds that the gaseous temperature be raised from the ignited feed mixture to 2000–3000° F.

The catalytic metal is released as a by-product by decomposition of the gaseous metal compounds of the metals such as nickel, aluminum, magnesium, platinum, chromium, copper, zinc, tin or their oxides. Where desired, the oxides, phosphates and stearates of the light metals, e.g., aluminum, magnesium and tin may be introduced into the second stage combustion chamber as an optional constituent to increase the catalytic action. The metal particles are colloidal and form during heat decomposition of the gaseous metal compound and which can be gasified and heat-decomposed to release the metal.

To permit the missile to withstand the variations in temperature to which it is subjected in flight through the atmosphere, it is preferably gas plated with a high temperature resistant metal such as zirconium or tungsten, the latter having a melting point of 3380° C., whereas zirconium metal withstands a temperature approximateing 2000° C. This gas plating deposits metal to form a thin, skin-like outer heat-resistant shell or coating.

Air temperatures at various heights above the earth to which missiles and space flight bodies are subjected are shown in the following table—

TABLE VI

Air Temperatures at Various Heights

Air layer name	Height, Miles	Temperature Range, ° C.
Trophosphere	0–10	+15 to −55
Stratosphere	10–20	−55 to +2
Chemosphere	20–50	+2 to −83
Ionosphere	50–250	+12 to 2,227

Table VI shows that while the temperature of the earth's atmosphere is relatively low in the lower layers, it increases considerably in the higher ionosphere layer. This accounts, to some extent at least, for heat destruction of meteorites and space satellites which enter the earth's upper atmosphere at high velocities.

The same reason it is, of course, necessary to fabricate the missile of materials which are sufficiently resistant to heat to withstand the range of temperatures to which it is subjected to during space flight above the earth.

In the starting of the jet motor by the burning of the propellant gaseous mixture and when the same is cold, a

stream of oxygen is introduced into the second stage combustion chamber so as to initiate the burning of the gases. After starting of the jet motor, the supply of oxygen is then cut back to that required to maintain the optimum combustion of the gaseous mixture.

The pressures in the chambers of the gaseous constituents are preferably maintained during the operation of the propellant motor so that the same will lie between 300 and 600 p.s.i. and preferably about 400 p.s.i. gauge, as aforementioned.

It is manifest that a wide range of gaseous mixtures and pressures and temperatures may be employed in the operation of the fluid jet motor to supply the thrust for driving the space vehicle and missiles of applicant's invention, and such modifications are contemplated to come within the spirit and scope of this invention.

What is claimed is:

1. A method of operating jet motors for propelling rockets and missiles which comprises feeding a fuel mixture of a volatile alkene selected from the group consisting of pentene-1,2-methylbutene-1, and 3-methylbutene-1, and containing 25 to 35% by volume nickel carbonyl, together with nitrogen and oxygen, into the combustion chamber of the motor, and burning the mixture to produce high temperature gases which are released as exhaust gases to propel the rocket or missile.

2. A method of operating jet motors for propelling rockets and missiles which comprises feeding a fuel mixture of a volatile alkene selected from the group consisting of pentene-1,2-methylbutene-1, and 3-methylbutene-1, and containing 25–35% nickel carbonyl, together with nitrogen and oxygen, into the combustion chamber of the motor, said nitrogen constituting 20–30% of the gaseous mixture and said oxygen constituting one-third by volume of the gaseous mixture, and burning the mixture to produce high temperature gases which are released as exhaust gases to propel the rocket or missile.

3. A method of operating jet motors for propelling rockets and missiles which comprises feeding a fuel mixture of pentene-1 and containing 25 to 35% by volume of a metal carbonyl, together with nitrogen and oxygen, into the combustion chamber of the motor, and burning the mixture to produce high temperature gases which are released as exhaust gases to propel the rocket or missile.

References Cited in the file of this patent

UNITED STATES PATENTS

1,305,340	Bostedo	June 3, 1919
1,405,482	Bostedo	Feb. 7, 1922
1,983,405	Schmidt	Dec. 4, 1934
2,744,380	McMillan et al.	May 8, 1956
2,757,509	Jendrassik et al.	Aug. 7, 1956
2,761,278	Jonas et al.	Sept. 4, 1956
2,765,617	Gluesenkamp et al.	Oct. 9, 1956
2,771,739	Malina et al.	Nov. 27, 1956
2,780,914	Ring	Feb. 12, 1957
2,815,270	Lawrence et al.	Dec. 3, 1957
2,927,849	Greblick et al.	Mar. 8, 1960