ASTRONAUTICS

No. 21 DAVID LASSER, *Editor* July, 1932

TABLE OF CONTENTS

ASTRONAUTICS is the official organ of the American Interplanetary Society and is published monthly for its members.

Associate Membership in the Society at $3.00 per year may be obtained by sending the first year's dues to the Secretary, C. P. Mason at 450 W. 22 St., New York. Information on other classes of membership may be obtained by writing the Secretary. Meetings of the Society are held monthly at the American Museum of Natural History, 77th St. and Central Park West, New York.

INCREASING THE RANGE OF THE ROCKET

By Harry W. Bull

[*This article, written at the request of the Editor, embodies the results of the experiments of Mr. Bull at Syracuse University. His results clearly open the way to further experimentation and offer many constructive leads to experimenters.* —EDITOR.]

Little scientific investigation has ever been made of the rocket combustion chamber. Even though it is one of the most simple devices for converting heat into work, the amount of time and money necessary to make an adequate research has been the great barrier. This research which was made on the rocket combustion chamber, extended over a period of eight months and only through the generosity of the University in giving me the use of their machine shop and laboratories was it possible to keep the expenses from becoming prohibitive.

Before any tests could be made it was first necessary to design some kind of a testing machine which would measure the recoil of the chamber, maintain a desired fuel pressure, show the fuel valve settings, and offer protection to the operators in case of explosions.

The external appearance of the apparatus designed for the testing of the combustion chambers is that of a large tube mounted on three supports at a convenient height above the floor. This tube merely acts as a safety enclosure for the test combustion chamber which it surrounds. Bolted to the inside of the tube are two metal runways for the ball bearings on which the chamber slides. The distance the chamber moves is recorded by a pointer which moves three inches for every one-eighth of an inch the chamber moves. A spring is attached to the chamber so that the recoil the unit is developing can be read directly from the scale above the apparatus.

Mounted on the side of the protecting tube are the two fuel supply tanks. They are made of tool steel and are capable of withstanding a pressure of 40,000 pounds per square inch. The oxygen container (for both liquid and gas) is fitted with a special relief valve which not only acts as a safety valve but also maintains any desired pressure on the fuel. To force the fuel into the combustion chamber a standard tank of oxygen was used.

Directly below the fuel tanks are the valves for controlling the flow of the fuel. The valves are equipped with dials so that the mixture setting may be read at a distance if remote control is used. Ignition was effected by means of an induction coil.

As a rule the tests were conducted in the laboratory at night, due to the danger involved if spectators were present. Although the actual test took only a few minutes, the substitution of a new design usually required a half hour. With the tanks filled with a measured amount of fuel under the desired pressure, a switch is thrown causing a stream of sparks to shoot across the nozzle of the combustion chamber.

As the valves are opened a jet of yellow flame darts from the mouth of the tube with a dull roar. Almost immediately the chamber warms up and the flame shortens and changes in color to a dazzling white. With this change the roar mounts to a deafening shrillness that continues throughout the test. When the fuel is exhausted the pressure in the combustion chamber drops causing a peculiar whistling noise. All data, such as the duration of the recoil, the kind and amount of fuel used, the heat generated by the combustion, and the pressure in the combustion chamber, is noted.

The Scope of the Research

In order to better comprehend the scope of the research it might be well to cite briefly the main characteristics of the types of combustion chambers which were tested.

(1) The Society's Primary Unit.
(2) Chambers of different lengths and diameters.
(3) Chambers with sloping and parallel walls.
(4) Chambers with opposed rear fuel injection.
(5) Chambers with forward spray fuel injection.
(6) Chambers with rear spray fuel injection.
(7) Chambers water and air cooled.
(8) Chambers designed for vaporizing fuel.
(9) Chambers with different nozzle diameters.
(10) Chambers with different fuel inlet diameters.
(11) Chambers using different fuels.
(12) Chambers provided with auxiliary air cones

Since it was impossible to cast the chambers, because of the large number necessary, some method was needed whereby they could be made more rapidly. It was finally decided to machine the units in sections and hold them together by a frame. The majority of units were made up of four sections of two-inch tool steel stock and were assembled in the following order:

(1) The rear section which consisted of a semisphere machined out of the center. In some cases this was drilled for fuel inlets.
(2) The rear center section which formed the combustion chamber walls.
(3) The forward center section which contained the fuel inlets and was curved to the rear of the nozzle.
(4) The forward section in which the nozzle was reamed.

These sections were then provided with gaskets and bolted together in a heavy frame, the outer edges of which were grooved to accommodate ball bearings. Not only could a chamber be made by this method in a fraction of the time that would be required to make a pattern and casting, but it also had the advantage of making possible the interchanging of different sections of one chamber with that of another.

Standards

In attempting to improve upon any device or machine, it is important to consider what has been tried before. This prevents repetition of past experiments and also provides a measure by which to gauge new advancements. In these tests it was first necessary to choose some chamber with which to make comparisons. For this purpose a water-cooled chamber similar in shape to the Primary Unit of Rocket Experiment Number I, which was designed by the research committee of the Society, was taken as standard.

Next it was necessary to establish a set of standard conditions by which to gauge the comparative value of the different designs. The following conditions were found to be most desirable after a few tests:

(a) Recoil - - - 2 pounds.
(b) Kind of fuel - Gasoline and Oxygen.
(c) Quantity of gasoline - - 100 c.c.
(d) Time to be the variable. That is, the chamber which will operate for the greatest length of time on 100 cc. of gasoline, while giving a recoil of two pounds, is the more efficient chamber.

For years it has been pointed out that the low efficiency of the rocket will prohibit it from ever being used as a means of transportation. Since the rocket combustion chambers, even at the present time, are exceedingly wasteful of fuel, it was decided to make the more efficient use of fuel the main objective of the research.

It is interesting to note that the final design tested ran over seven times as long as the Primary Unit; both using the same amount of fuel and giving the same recoil. To better understand the practical value of this let us consider a comparative example of two rockets. Each rocket has a total weight of one pound, both have the same amount of fuel, and both give a recoil force of two pounds. The only difference between the rockets being that the first is powered with a chamber similar to the Primary Unit while the second is powered with the improved design last tested.

Under favorable conditions the fuel in the first rocket would last for one second and an altitude of some thirty feet would be reached. But the improved design will use the same amount of fuel much more efficiently and hence the fuel will last for over seven seconds at the end of which the rocket will have reached an altitude of some FIFTEEN HUNDRED FEET.

The four improvements in design which so greatly increase the range of the rocket, embody known principles of Thermodynamics that have been overlooked in the design of rocket units in the past. Because of the specialized technical knowledge required, no explanation for the reasons of the following design features will be given.

The Primary Unit — This chamber was water cooled, had forward fuel injection, and had parallel chamber walls. Under standard conditions this chamber ran for FIFTEEN SECONDS.

Design I—This chamber was similar to the Primary Unit in that it was water-cooled, and had forward fuel injection. It differed in that the sides of the chamber were sloping and that the ratio of the length of the chamber to the diameter was two to one. By using a chamber which is not of the right proportion the cooling surface becomes too large for the chamber volume and the efficiency is greatly impaired. Under standard conditions this chamber ran for TWENTY-FOUR SECONDS.

Design II—This chamber was identical to that of Design I with the exception that it was air-cooled by means of fins welded to the outside of the chamber. As to how much longer an air-cooled motor will run than a water-cooled one depends upon the temperature at which the air-cooled motor is allowed to operate. For this reason no set figure can be stated. Under standard conditions this chamber ran for FORTY-FIVE SECONDS.

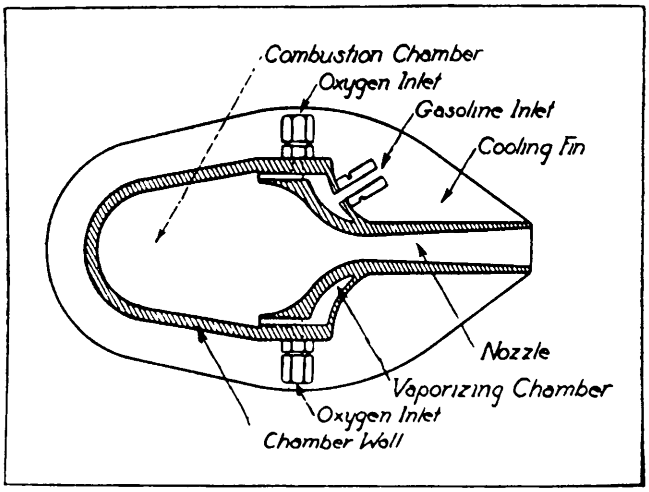
Design III—Chamber was identical to Design II with the exception that the fuel was vaporized before it entered the chamber. This was accomplished by circulating the fuel around the front part of the heated unit. Because of the close relationship between air-cooling and vaporization it is difficult to secure a sharp distinction between the two in regard to the exact time each prolongs the operation of the motor on a given amount of fuel. Under standard conditions this chamber ran for FIFTY-SIX SECONDS.

Design IV—Chamber was identical to Design III with the exception that the nozzle was surrounded with a Venturi-shaped cone some 15 inches in length. Under standard conditions this chamber ran for ONE HUNDRED AND TEN SECONDS.

The final design (illustrated) has four gasoline and eight oxygen inlet ports. The chamber is of tool steel and the cooling fins welded to the sides. The entire assembly is made up of five pieces. When in actual operation an air cone is attached.

Different kinds of fuels were consumed in the same type of chamber and the time in which a fixed amount of fuel, at a definite recoil value would be consumed was noted. As might be expected, knowing the large number of B.T.U.'s per cubic foot, gasoline seems to be the most feasible hydrocarbon. Alcohol, while it does not yield as much power as gasoline, is a very convenient fuel to work with since it seldom backfires and produces a short violet flame. The following fuels were tested:

Gasoline and Ether	58 sec.
Gasoline	55 sec.
Kerosene	42 sec.
Oil	34 sec.
Alcohol	25 sec.



This illustration shows the final design of a rocket combustion chamber of Mr. Bull, as mentioned in his article. It will be noted that the fuel inlets are at the nozzle end of the chamber, instead of the rear end of the chamber, as was the case with earlier designs.

Other Facts Learned from the Research

(1) *Fuel Inlets*:—The most satisfactory position for the fuel inlets seems to be in the front part of the chamber. It was found to be impractical to spray a mixture of gasoline and oxygen through the same port, for any great varia-

tion of the mixture will often result in the burning of the chamber walls. It is also of great advantage to have a large number of small inlet ports rather than to have just two large ones. This practice gives a better mixture, wastes less fuel, and increases the efficiency.

(2) *Backfiring*:—Opposed inlet ports, too small a nozzle diameter, and pre-mixing all cause excessive backfiring into the fuel tanks. The ordinary backfire trap often became saturated with fuel and hence offered but little protection. A special trap was designed in which a light aluminum valve sealed the fuel line when the pressure started to fall. This valve proved very satisfactory and removed the danger of the steel fuel tanks exploding.

(3) *Combustion Chamber length*:—If the fuel is vaporized before entering the combustion chamber, the chamber may be very short. With air-cooling the chamber may be further shortened. As a general rule, where the fuel is vaporized, the chamber length should be twice the chamber diameter. Proportions will, however, vary according to the quantity of the fuel burned per unit of time.

(4) *Exhaust Noise*:—It is unfortunate that no means of silencing the noise of the escaping gases has been found. It is imperative that the nozzle be as smooth as possible. Any slight irregularities in the nozzle surface will result in an irritating noise of great intensity.

(5) *Auxiliary air cone*: — The power of a rocket may be greatly increased by surrounding the nozzle with a suitable casing. In tests a single length of tubing some three inches in diameter and fifteen inches long was placed slightly in front of the nozzle. With this arrangement a great increase in power was noted. By substituting another stage or even two more expansion stages the power could undoubtedly be increased.

(6) *Air-cooling*:—It was found during heat tests that even though the motor was under little load (2 lbs.) it required approximately 2 cu. cm. of water per second to keep it cool. With an increase in load naturally more cooling water would be necessary. It follows then that to cool a motor by air would require many fins having a large area exposed to the air. Short fins (¼") which have been used on some types of rockets are totally inadequate for the purpose.

(7) *Nozzle cooling*:—In heat tests it was noted that while combustion took place in the center of the chamber it was the nozzle that first became red hot. In any rocket combustion chamber design provision should be made for cooling the nozzle for at least two-thirds of its length.

(8) *Fuel vaporization*:—Partially cooling the chamber by using its heat to vaporize the incoming fuel is strongly recommended. Not only will the efficiency of the motor be greatly increased through raising the temperature of the fuel but the vaporization will result in a better mixture of the products of combustion. If the fuel is allowed to enter the chamber in the gaseous state the inlet ports should of course be larger proportionally than if the fuel was allowed to enter in the liquid stage.

(9) *Burning of chambers*:—If any gaskets are used in connection with the combustion chamber of the rocket special care must be used to see that they are kept tight. Any leakage will result in the burning of the chamber beyond repair.

At the end of the research a design, embodying all those requisites for the most economical use of fuel, was tested. Although this final design is undoubtedly far from the ultimate goal, it surpasses, to my knowledge, any of the rocket power units of today.

GODDARD EXPERIMENTS TO BE DISCONTINUED

A communication from Dr. Robert H. Goddard, to the Editor of *Astronautics* announces the discontinuation, owing to the depression, of Dr. Goddard's experiments on rockets at Roswell, New Mexico.

Dr. Goddard had been working on meteorological rockets at Roswell since 1930, endowed with a fund of $100,000 by the late Daniel Guggenheim.

Dr. Goddard states that he will resume his teaching position at Clark University, where his early work on rockets was carried on.

NEW ASTRONAUT ARRIVES

A new astronaut entered the family of G. Edward Pendray, president of the American Interplanetary Society and Lee Gregory (Mrs. Pendray), librarian of the Society, on June 14.

The space traveler, a girl, was named Guenever Lee. The Society offers its congratulations.

THE PHYSIOLOGY OF ACCELERATION

A Report of Experiments by the Experimental Committee, American Interplanetary Society

On June 18th, 1932 the committee on Biological Research subjected two guinea pigs to centrifugal force with the object of determining their reaction. A centrifuge was used having a diameter of 2 feet and revolving at 600 r.p.m., obtaining an acceleration force of about 30 gravities. The pigs were wrapped in heavy soft cotton socks with large air-holes cut for breathing. The animals were braced against the broad vertical outer rim, tied in place, and turned head foremost, so that the increased weight would come on their four feet when the centrifuge was put in motion.

The speed was attained gradually, over a period of about 20 seconds and was maintained for two minutes then gradually brought to a stop. Both animals were dead immediately upon removal—there being not the slightest sign of life. The autopsy was at once performed and findings were as follows:

Pig No. 1—(black) Autopsied about 10 minutes after death. Healthy normal animal. About three weeks old. Weight 260 grammes.

External appearance: Slight nose bleed.

Peritoneal cavity: About ½c.c. dark blood pooled about the colon.

Bladder: Distended with about 1 c.c. of clear fluid.

Intestines: Normal.

Stomach, Kidneys, liver, spleen: Normal.

Heart: In diastole. Gorged with clotted, dark red blood in all four chambers.

Lungs: Normal.

Cranium: Small area of dark clotted blood beneath the pericranium over the occipital bone.

Brain: Normal.

Eye and ear cavities: Normal. No blood in passages.

Spine: Fracture in the atlanto-axial region. Cord not injured.

Cause of death: (see remarks).

Pig No. 2—(brown) Autopsied about 30 minutes after death. Normal healthy animal weight 290 grammes. About 3½ weeks old.

External appearance: No nose bleed.

Peritoneal cavity: About 1 c.c. of dark blood pooled about the colon.

Bladder: empty.

Intestines, Stomach, Liver, Spleen, Kidneys: Normal.

Heart: In diastole. Gorged with clotted, dark red blood in all four chambers.

Lungs: Normal.

Cranium: A dark red clot, area about 1 sq. cm., of blood beneath the pericranium over the occipital bone.

Brain: Normal.

Eye and ear cavities: Normal. No blood is passages.

Skull: Lower jaw dislocated.

Trunk: Upon removal of skin, an effusion of dark clotted blood was observed in the superficial fascia, an irregular area from the occipital bone to about the 5th thoracic vertebra about 3 cm. wide.

Spinal column and cord: No injury observed.

Cause of death (see remarks)

Remarks: On autopsy, the outstanding clue to the death of the two animals was the clotted blood in the hearts. Under no circumstances could this be taken for post mortem clots, the autopsies being performed ten and thirty minutes after death. Neither could these clots be taken for signs of asphyxia, as the left as well as the right side of the heart was involved in both cases, which would not be the case in asphyxia. And moreover, guinea pigs can hold their breath for two minutes without suffocation.

It seems likely that the heart muscles were unequal to moving the enormously greater weight of blood and that the hearts became gorged with blood which they were unable, due to sheer exhaustion, to expel. While this may be taken as the probable cause of death in both cases, yet there are two other definite possibilities:—

(1) The two clots of blood on the cranium in each case probably were caused by occipital blows and such blows might have caused concussion of the brains, even though the brain itself appeared normal.

(2) Shock is a subject not thoroughly understood by medical science. It may have caused or contributed to the death of the two animals. In addition to the great increase of weight experienced, which might have produced shock, hemorrhages were seen in the peritoneal cavity, showing some injury there, and the loss of blood though small would tend to produce shock as well. (Although neither animal lost enough blood to do serious physical damage.)

One of the pigs had a fractured spine, but the cord was not injured and the fracture was simple and was not likely to have caused death immediately, although it would perhaps have contributed to shock, if shock existed.

It is interesting to note that certain symptoms popularly supposed to exist in such cases were not found: One bladder was distended with fluid and was not forced to discharge it. Also, while one animal did have a slight nose bleed, this was probably caused by a blow and the other animal had no such nose bleed at all, nor in either case was there any sign of blood vessels breaking in the eyes or ears, nor were any large veins or arteries ruptured in their bodies.

Conclusions: That the experiments by Messrs. Schmidt and Norton last year with white mice (which withstood acceleration forces upwards of 80 gravities) do not show the ability of larger animals such as guinea pigs to withstand acceleration: And that, in the case of a human, our experiment tends to indicate that man will not be physically capable of withstanding very much higher rates of acceleration than those limits now set by present physiological theory.

Recommendations: We propose to undertake confirming experiments and until the completion of these, we recommend that the above conclusions be not considered final.

THOMAS W. NORTON
LAURENCE E. MANNING.

New York, N. Y.
June 13th, 1932.

CARBON DIOXIDE DISCOVERED IN ATMOSPHERE OF VENUS

Discovery that carbon dioxide is probably present in the atmosphere of the planet Venus, nearest planetary neighbor of the earth, was announced by the Carnegie Institution of Washington.

Speculation as to the existence of life on the earth's twin sister planet will be revived by the studies of the infra-red or heat spectrum of Venus made with the world's largest telescope, the 100-inch reflector, at Mt. Wilson, Calif., Observatory by Dr. Walter S. Adams, director, and Dr. Theodore Dunham.

The reported discovery is also notable because it is the first time that a gas of any kind has been detected upon any planet except the earth.

For years it has been known that Venus is covered with an atmosphere of considerable extent. Upon the rare occasion of the transit of Venus, when it passes in front of the sun, the planet is surrounded by a ring of light when it is in line with the edge of the sun. This light aura is due to refraction of the sun's rays by the atmosphere of Venus. Clouds cover the surface of Venus so completely that it is believed that astronomers seldom if ever see its real surface and the thickness of the atmosphere below the clouds is estimated to be about 4,000 feet.

Drs. Adams and Dunham used a powerful telescope and spectroscope on the infra-red sunlight reflected from Venus and discovered that three bands of invisible heat-light were missing. These were absorption bands that they concluded were due to carbon dioxide in the Venus atmosphere cutting off these particular wave lengths as the light passed through the planet's atmosphere.

Previous searches for Venus gases, such as oxygen, water vapor and carbon dioxide, all essential to life as we know it on earth, were fruitless.

Carbon dioxide is the gas given off by animal and plant breathing and used by plants in the making of starches and sugars. Its discovery on Venus will justify renewed discussion of the possibility of life of some sort on that planet. Research has shown that the surface temperatures of Venus are somewhat like those of the earth although probably warmer. If future researches should show oxygen and water present, life on Venus might be considered more probable.

"This discovery, if fully substantiated," the institution's announcement asserted, "is of marked scientific interest for two reasons. It will have been the first time a gas of any kind has been identified in the spectra of any of our planets, and it indicates that one of the essentials to life as we know it on this earth may exist in the atmosphere of Venus.

"This most brilliant of all celestial bodies, except the sun and moon, resembles the earth in so many ways that it has been called the earth's 'twin sister.' It is eight-tenths as massive as the earth, is more highly reflecting, is two-thirds as far from the sun and has a gravity pull about four-fifths as powerful. Inasmuch as its density is about nine-tenths that of the earth's, it is believed to have a solid surface.

Atmosphere Plainly Visible

"That Venus has a fairly dense atmosphere is certain, for it is plainly visible when this planet is in a certain position between the earth and sun. Then it presents an appearance which would be caused by sunlight illuminating the planet's atmosphere from behind.

"Whether this atmosphere contains the essentials for life has been a baffling mystery, for its constituents have remained an enigma. Now, however, through use of the spectroscope, that amazing tool of the astronomer, a substantial clue to the nature of the atmosphere of our 'twin sister' has been obtained.

"In practice, light rays from the planet are gathered up by the telescope and focused upon the slit in the spectroscope whereupon they are broken up into their spectral groupings. Light coming from Venus, being reflected sunlight, must have made a double passage through at least the upper strata of the planet's atmosphere before passing through the earth's atmosphere. During passage through these atmospheres it suffers absorption by the gaseous elements and compounds which it encounters in its path.

"The presence of every gas or compound in the light-path is registered in the spectrum by a dark line or band which occupies a characteristic position. The position of a line or band in the spectrum identifies the gas or compound through which the light passes. This is the 'thumb-print' so to speak, by which it can be recognized.

"Earlier spectroscopic studies of the light from Venus failed to reveal any lines and bands which would serve as a clue to the nature of the constituents of the atmosphere through which it passed. When, however, Dr. Adams and Dr. Dunham availed themselves of the superior light-gathering power of the 100-inch telescope and also turned to the infra-red region of the spectrum in search for the identifying lines and bands these were found in the position which carbon dioxide would naturally occupy.

"It therefore appears that even the atmosphere of Venus bears resemblance to that of the earth, for apparently it contains at least one of the essentials to the maintenance of life as we know it on the earth. However, whether life in any form has actually gained a foothold on this interesting planet remains a matter of pure speculation."

Following this discovery there comes the news that a powerful telescope at the Lowell Observatory in Arizona has pierced the cloud layers of Venus and a first glimpse of the planet's surface has been obtained. Hazy markings were revealed, whose nature none could guess.

At the summer meeting of the American Association for the Advancement of Science at Syracuse, N. Y. the significance of the new discoveries on Venus was discussed by astronomers. It was pointed out by Drs. Adams and Dunham of Mt. Wilson that no evidence of oxygen or water vapor had yet been found. Some doubt was expressed as to whether the surface of Venus had actually been seen.

Dr. Philip Fox, director of the Adler Planetarium Chicago, assuming. that the Venus day were 20 earth days long, and the Venusian night equally as long (making the revolution of Venus on its axis 40 earth days) stated that life if it exists on Venus must be very hardy or "tough." The change from the long day to the long night would require creatures very adaptable.

(Two objections might be made to Dr. Fox' conclusions. The first is that he assumes life on Venus, but he does not assume perhaps millions of years of adaptation to its environment. He takes an arbitrary standard of earth conditions as that being most ideal for life. As a matter of fact, it may be that the 40 (earth days) period of Venus might be conducive to Venusian life. Since the planet is covered with a heavy blanket of atmosphere, a great deal of the sun's heat is reflected. Of that which enters the atmosphere, much is retained when the Venusian night arrives and therefore keeps the planet warm. Even on earth, where we receive only about 40 percent of the sunlight that Venus does, the sun's summer heat is sufficient to keep the earth hot during the night hours.

Secondly, it may be that a day and night much longer than our own may conduce to longer life. Venusians observing us, and our 12-hour alternations of day and night might think that we live frenzied lives, readjusting them frantically every 12 hours. Venusian life may be more calm and more enduring.

Finally it might be said that Dr. Fox gives the impression of a sudden, shift from summer heat to wintry cold, during the rotation of Venus. As a matter of fact, a Venusian sunset might conceivably last for four earth days, during which the inhabitants of the planet would become gradually accustomed to the changing temperature. A sunrise might be equally long.—*Editor.*

LATEST ROCKET PLANES FOR THE STRATOSPHERE

By Noel Deisch

(*This article, by one of the members of the American Interplanetary Society, has been reprinted from the July, 1932 issue of* Popular Aviation *by permission of the editor.)*

Many aeronautical engineers feel very sure that when the stratospheric plane comes it will be driven in its long arc from continent to continent by a reaction-motor or rocket.

The reason, as pointed out with due mathematical argument, is that in air of the density that exists at a height, say of 50 or 100 miles, and at the speeds at which it is hoped that a stratospheric plane in its ultimate development will travel, about 600 m.p.h., a rocket will be both more efficient and more practical than the conventional engine-driven screw propeller.

However, every stratospheric plane must, through an important portion of its flight, progress under conditions very different from those that obtain when it is, so to speak, in its own proper element. It must begin by making what would at present be thought of as a stupendous altitude flight before getting fairly into the main span of its journey.

During the first stages of this climbing flight, when its speed is comparatively low and the atmosphere is dense, the efficiency of a machine propelled by direct rocket action must inevitably be very low indeed. During this period then, propulsion by conventional screw-propellers is vastly to be preferred over rocket propulsion.

On the other hand, we are reluctant to conceive of a craft as being encumbered during the whole of its journey by a heavy engine which is called into requisition during only a brief portion of its flight.

Doctor Goddard, of rocket fame, not long ago suggested a solution to the difficulty just indicated in which the virtues of the propeller and the rocket are combined into a single structure. The rocket burns continuously, not only during the high altitude portion of the plane's flight, but from the moment it takes off.

However, in the earliest stages of flight, the discharge from the rocket does not drive the plane directly by its own reaction, or at least only secondarily so, but rather it is used to turn a pair of ordinary screw propellers which themselves act on the air to impel the plane forward.

These propellers are fitted with circular rims containing turbine blades which dip into the rocket jet and transfer energy from the jet to the propeller proper. In other words, the air propeller is closely associated with a gas turbine rotor. When the higher regions of the stratosphere are attained, the propellers with their turbine rims are moved by means of an adjustable bracket away from the jet, and the plane continues its flight as a simple rocket-driven airplane.

Thus, by Dr. Goddard's ingenious suggestion the special virtues of the propeller and of the necessity of providing an engine of the usual type is obviated, that much weight being saved for pay-load and fuel. However, the mechanical embodiment of his idea does not appeal to some aeronautical men as being wholly air-ship-shape.

The ring of turbine blades is necessarily quite heavy, since the peripheral speed is very great, calling for a substantial construction to withstand the tangential stresses generated.

To reduce this weight, the propellers must be kept to a diameter which does not speak for good aerodynamic efficiency. Then, the rims and shiftable supporting apparatus are such as to offer greater air resistance than is desirable in a craft designed for the highest attainable speed.

Let us consider another application of Doctor Goddard's principle which allows of the use of a plane of more nearly conventional design.

In this case agàin the propeller is jet-driven, but the driving turbine is of a pure reaction rather than of the impulse-reaction type. We have a single propeller located out at the forward end of the fuselage as in usual practice. At the top of each propeller blade is a jet-propulsor, fed by liquid fuel which is carried down the length of the blades in pressure tubing. The jet from the propulsor escapes tangentially and produces a moment which rotates the propeller on its axis much after the manner of a pin-wheel.

At the high peripheral speeds attained in an air-propeller, the rocket motor would act with an efficiency approaching, though hardly attaining, that of the usual gasoline engine. In the present arrangement, moreover, the propeller is of the adjustable-pitch type:—in fact each blade can be adjusted from the minimum or take-off pitch to a pitch of substantially 90 degrees.

As the plane gradually rises through the atmosphere, into strata of constantly decreasing density and as its speed gradually increases, the pitch of the propeller is progressively changed to higher angles. Finally, when the machine has reached its designed altitude for flat travel, the blades will have been set to an angle where they offer minimum resistance to the forward progress of the plane.

At this angle, the jet-propulsors are pointed almost directly astern and act as simple rockets, the screw-propeller being held stationary or allowed to rotate at greatly reduced speed. In this way, we attain a gradual or continuous transition from simple propeller action to direct jet-action, and with no serious departure from usual design aside from what is inseparable from the use of jet-propulsion methods.

By use of that device, the reaction-driven propeller is of large diameter to adapt it to efficient operation at extreme altitudes, it being mounted considerably above the axis of the ship to provide proper ground clearance for starting or landing.

To make steering certain, even at the highest altitudes, a universally mounted auxiliary jet propulsor, is actuated in its pivotal motions by the usual steering apparatus and hence moves in unison with the vertical and horizontal rudders.

It need hardly be stated that this auxiliary propulsor would also add to the driving effort applied to the plane and might be brought into requisition for this purpose alone as soon as altitude and speed conditions warranted its use.

Of course, there is an objection to both of these embodiments of Doctor Goddard's suggestion for driving the propeller, as opposed to the use of a gasoline engine, in that both call for the storage of oxygen aboard the ship for the purpose of forming a combustible mixture.

In the case of a gasoline motor, this oxygen is taken directly from the air with a very considerable saving of weight. There is, moreover, to be considered the practical fact that at the present date the fuel injection reaction motor for continuous duty is still entirely a matter of theory or of tentative experimentation.

Foremost among the questions, yet to be solved, are those of providing a combustion chamber and nozzle that will withstand the tremendous eroding action of the exceedingly hot and highly compressed combustion gases, the provision of a satisfactory combustible mixture, and (though this is rather a matter of mechanical design) a practicable pump and accessory apparatus to convey this mixture at a controlled rate to the combustion chamber.