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The de Havilland Vampire

BRITISH JET PLANES EXCEED 600 M P.H.

Third and latest of Britain's jet propelled aircraft is the Vampire, a single-seater fighter. Designed by the de Havilland Aircraft Co., who also designed its one Goblin turbo-jet engine, the Vampire has a top speed of 540 miles an hour at 20,000 ft., and a rate of climb over 4,700 ft. a minute. In experiments the jet plane has landed on aircraft carriers at a 95 miles an hour speed.

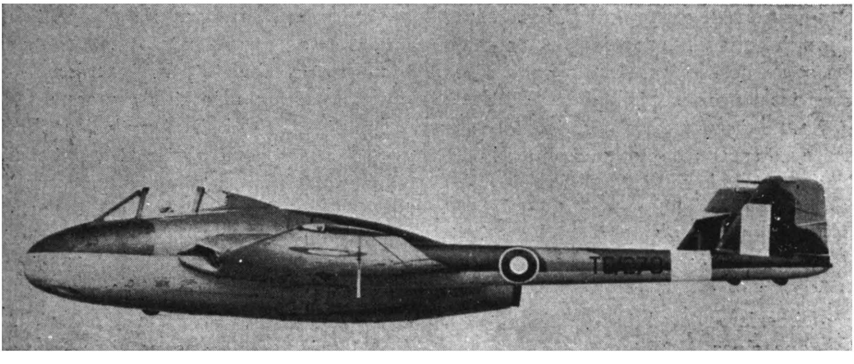
The plane is a mid-wing monoplane with a central nacelle carrying pilot and engine, twin booms for the tail plane, twin fins and rudders. An air-intake duct is on each side of the fuselage and a single exhaust outlet is located at the rear. Four 20 mm. cannon are placed in the lower fuselage. The all-metal Vampire has the following dimensions: span, 40 ft., length, 30 ft. 6 in., height, 9 ft. 9 in., and wing area, 248 sq. ft. Work on the Goblin gas-turbine engine was started in April 1941, and the engine was tested a year later. In 1943 the Goblin was used in test flights of both the Gloster Meteor and Lockheed Shooting Star.

Speed Records

Two British jet-propelled Gloster Meteors set new unofficial world air speed records of over 600 miles an hour at Herne Bay, on the south coast of England, November 7th. The present air record of 469.22 m.p.h. was set by Fritz Wendel, of the German Luftwaffe, in a special Messerschmitt 109 fighter plane, April 1939. An unofficial mark of 570 miles an hour is claimed for the Lockheed Shooting Star.

Flying back and forth over the regulation international three kilometer (1.86 miles) course, Chief Test Pilot Eric Greenwood, of the Gloster Aircraft Co., built up momentum by 60 mile flights to average 603 miles an hour in four runs. Group Captain H. J. Wilson, of the R.A.F., made an average of 606 m.p.h., once reaching 611 miles an hour. The course was marked with colored lights and balloons, while cameras and radar devices clocked the flights.

It is interesting to note that Great Britain now holds the three world speed records—land, air and water.



—British Official Photograph

British Vampire—Side view shows one of the two air-intake ducts for the gas-turbine engine.

Helicopter Reaction Propeller Drives

Jet Propulsors For Rotary Winged Aircraft

By CEDRIC GILES

With scientific research increasing in the application of jet propulsion for aircraft the development of craft lifted vertically by rotating airfoils driven by the reaction of ejected gases is in the not too distant future. Of the many methods proposed for perpendicularly lifting and sustaining a craft by free jets of gas discharging downwards, jets working against surfaces, or jets driving airfoils, the latter form not only appears the most interesting but applies especially to the present helicopter type of aircraft. An earlier article* on the subject gave a brief history, and reviewed air jet arrangements, combustion gas ejection, propeller jet propulsors, and reaction driven rotors as applied to rotary wing flight.

Reaction propeller drives as a means of convenience can be divided into three main classes based on the propellants used and method of utilizing thrust. In the first class atmospheric air is drawn into the aircraft and force-fed by pumps or blowers through passages in the rotor shaft and blades, and upon being forcibly ejected through outlets provides a reactive thrust to the blades. The second class employs combustible fuels, with or without air, delivered separately or as a single mixture and burned in combustion chambers. A few borderline helicopter jet drives because of their peculiarity of design or indirectness of applying thrust do not fall readily into the first two groups and are therefore listed in a third miscellaneous class.

Jet Advantages

The principal advantages accredited to the use of jet propulsion for actuating free turning rotors mounted on stationary shafts of rotary winged aircraft may be listed as:

1. Means of neutralizing torque.
2. Simplifying initial power source.
3. Elimination of complicated gearing.
4. Less weight and drag.
5. Better stability.
6. More effective control.
7. Lower possible speed of rotor blades.
8. Use of additional rotors.

The problems on the other hand involve the difficulty of designing effective rotor blades, heat loss of the gases during transit, leakage of the fluid flow channels, fire and heat hazards where burning gases are used, blades rotating through the driving jet and high fuel consumption.

Air Jet Designs

The simple self-propelled rotor as shown in Fig. 1 compresses the air in the hollow blades through centrifugal action and expells it from metering orifices located at the blade tips. Jet reaction, resultant of momentum increase in the jet fluid stream by thermal or mechanical means, is tangential to the helical path described by the rotating blades as the aircraft advances. With blade tips approaching the speed of sound the jet velocity can be regulated to give a fairly good efficiency. A decrease in efficiency will result if the jet speed in relation to the blade becomes too great. With free turning rotors the need for torque counter, such as produced by anti-torque rotors, opposite to the torque force of main rotors becomes unnecessary. The use of a "hammerhead"

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*Jet Propelled Helicopters, Astronautics, No. 55, July 1943.

propeller in lieu of the orthodox shaped rotor blade for tip drives represents a novel idea. First tried out on a small plane a few years ago, the hammerhead type of propeller can be readily modified to meet inherent requirements.

Another method sketched in Fig. 2 suggests multiple slots or a long slotted nozzle along the blade. In this system a large mass of air is ejected at low velocity, consequently the rotation energy loss is small. The main disadvantage of air ejection appears in the need of a powerful blower with its accompanying driving mechanism.

A single-arm wing is shown in Fig. 3 which upon rotating around a centralized turret gives a lift to the aircraft. Air is forced through the interior of the wing by a blower and out multiple openings in the wing tip thereby producing a reaction. The blower mechanism placed in the base of the wing counterbalances the jet.

In Fig. 4 a double wing rotates around a central hub containing a blower for drawing the air from above and impelling it through the hollow wings. The two wings balance each other and the issuing air from the tips supply a thrust force always on opposite sides of the rotor hub.

Various designs suggesting wings actuated by air jets are described in French patents Nos. 440.593 and 440.594 granted to MM Papin and Rouilly in 1911. The Papin-Rouilly Gyropter shown in Fig. 5 was built after the last war but never succeeded in leaving the ground. Operating in a manner similar to Fig. 3 the giratory action from the rotating wing is compensated by a jet of air expelled through an L-shaped tube manipulated by the pilot in the turret-head.

A year ago Director Donnell W. Dutton at the Georgia School of Technology revealed a working model of a jet propelled helicopter. Air, pulled in through the nose of the scaled model by a high-speed axial blower, passed through the hub and was discharged at the tip of the helicopter blades. With no mechanical connection between rotor and fuselage torque reaction was insignificant and the elimination of the anti-torque propeller was foreseen.

Combustion Gas Arrangements

Utilization of the exhaust of ordinary helicopter engines for creating a motivating source of energy seems a likely possibility when considering the manner of attaining additional thrust by the backward pointing exhaust stacks of airplane engines. The simplest method employs a swiveling exhaust pipe, controlled by the pilot, for counteracting torque, and assisting in stabilizing and steering the helicopter. It has been suggested that the efficiency of the standard helicopter could be improved by allowing the combusted gases of the engine to exhaust through the blades of the main rotor. Substituting for the auxiliary or anti-torque rotor are proposed airscrews driven by the reaction of exhaust gases issuing from the blade tips.

In a number of designs the fuel is delivered under pressure to the nozzles where air for combustion is derived from the surrounding atmosphere. Ignition of the combustible mixture is accomplished by either a spark or hot wire. The combustion of the mixture develops a high temperature in the nozzle which will probably require some form of cooling. Where possible the nozzle outlets are mounted on the propeller blades for the most effective pitch arrangement. The application of Figs. 1-5 for combustible fuel dispositions has numerous possibilities.

The rotating of a device by discharging jets tangentially was first achieved by Hero of Alexandria in his famous aeolipile about 130 B.C. As illustrated in Fig. 6, steam, formed in the water boiler, passes to the sphere by way of a hollow trunnion and upon escaping from radial pipes with right-angle ends causes the globe to rotate opposite to the steam jets, in the same manner that a stream of water turns the arms of the common lawn sprinkler.

Aircraft Development

For ordinary aircraft the development of propellers actuated by jet devices has found favor among a number of investigators. The best known reference on this subject is the N.A.C.A. T.M. No. 571, translated from La Technique Aeronautique by Maurice Roy. A number of arrangements are considered including the scheme in which atmospheric air enters the forward facing intake, is compressed in the rotating hollow blades, and together with fuel is combusted in the nozzles, as indicated in Fig. 7. With the propeller handicapped at sonic speeds a solution appears in the thin atmosphere of high altitudes where the propeller can be locked stationary and progress made by pure jet action much in the manner of the ramjet (athodyd). In extreme altitudes the air for combustion would necessitate it be carried along.

By having cuttings in the blades the air stream may be so regulated as to eliminate the greater part of the present noise attributed to the propeller which supplies more than 75% of the clamor of the plane. One idea proposes tunnels through the blades of engine driven rotors of such shape as to scoop in air for jet combustion purposes. The drawing marked Fig. 8 refers to a thrust augmentation plan whereby motive fluid from pumps or the exhaust of the engine is ejected towards the trailing edge of the blade. Air in transit through passages is expanded by applied heat and leaves the thrust augmentor with increased velocity.

The drawing of U. S. patent No. 2,330,056 issued to F. A. Howard as in Fig. 9 relates to a combination helicopter and autogyro design. The regular aircraft engine not only is fitted with a propeller but is also arranged to drive a blower which delivers a combustible mixture of the engine fuel, gasoline and air, to combustion chambers on the ends of the rotor blades. The hot gas stream emanating from the blade tips impels the blades in an opposite direction, providing a lift to the aircraft. Engine exhaust escapes directly to the air or may be diverted to the combustion chambers during flight. Up to 90 per cent of the full power output of the engine may be absorbed by the blower, the remaining 10 per cent being sufficient for minimum propeller requirements.

British Proposals

An earlier British Patent Specification No. 336,450 granted to F. A. Howard describes turbo-propeller innovations. In the system exemplified in Fig. 10 fuel and air are furnished by way of the hollow shaft to combustion chambers situated near the axis of the rotor. Exhaust gases pass to the blade tips via tubes which may be adapted to form the leading and trailing edges of the blades. Combustion chambers on the propeller blade rims and vertical shafts which may be swiveled for obtaining the best thrust and tilted for forward propulsion are also discussed.

British patents obtained by C. G. Pullin of G. & J. Weir, Ltd., relate to a helicopter having a free running rotor propelled by reaction nozzles on the blades. As shown in Fig. 11 the Weir-Pullin helicopter uses a forward mounted turbine-compressor unit which delivers air to the combustion chamber where a suitable fuel is burned. The high temperature gases travel through the rotor hub, the interior of the blades, and out the trailing edge of the blade tips.

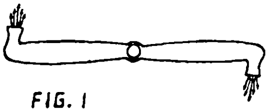


FIG. 1

FIG. 2

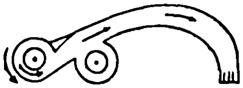


FIG. 3

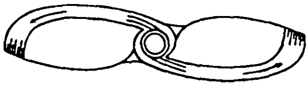


FIG. 4

FIG. 5

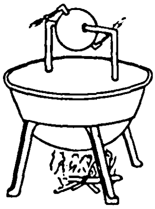


FIG. 6

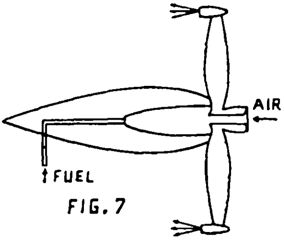


FIG. 7

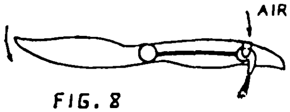


FIG. 8

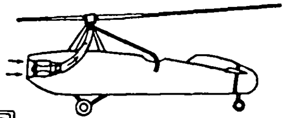


FIG. 11

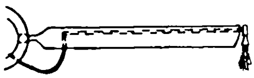


FIG. 9

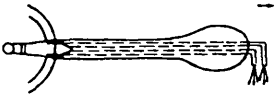


FIG. 10

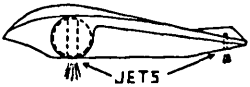


FIG. 12

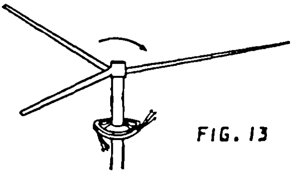


FIG. 13

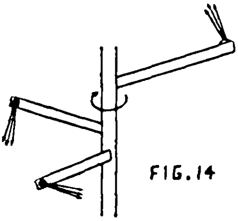


FIG. 14

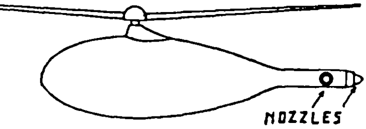


FIG. 15

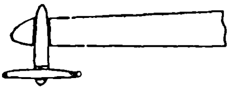


FIG. 16

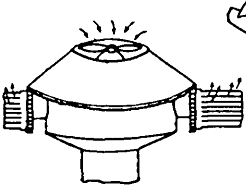


FIG. 17

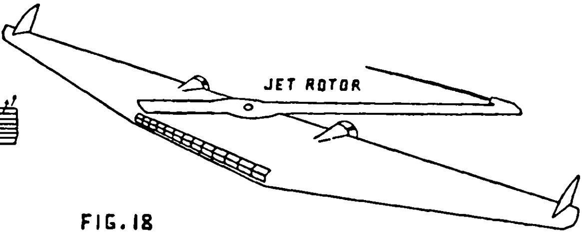


FIG. 18

C.G.

A direct lift wingless aircraft proposed by Richard Lonsdale-Hands at the 1943 exhibition of the British Institute of Civil Engineers is depicted in Fig. 12. Lift, propulsion and control of the craft is achieved by three movable jets. The two main jets on either side of the fuselage swivel from a vertical to a horizontal position at the desired altitude for forward flight. The supplementary tail jet provides lift and control. As the craft is intended for super-sonic flight wings are dispensed with.

Miscellaneous Reaction Schemes

Rather than blade jet propulsors one interesting version uses jets mounted on a horizontal ring fastened to the vertical rotor shaft. As pictured in Fig. 13 rotary action of the jet propelled whirligig rotates the rotor shaft and in turn the securely attached overhead propeller. Any loss due to air resistance and leverage action is hoped to be overcome by better propeller streamline efficiency. Any feasible number of these rotary jet accelerators can be mounted on the same or different rings.

A modification of this idea places the jet exhausters on spokes arranged in staggered fashion singly or in small clusters along the rotor shaft. This arrangement, Fig. 14, attempts to eliminate to a large degree air disturbance, and lessen hot exhaust accumulating in the same plane at the same instant with less chance of burning the nozzle.

The modified sketch, Fig. 15, illustrates the Helicospeeder, a jet helicopter designed by Antoine Gazda, which has actually been flown. The engine-driven single rotor spins the two blades at the most effective inclination angle, with the least air resistance. The main tail jet provides forward propulsion while two opposite tail jet nozzles control steering and torque control.

Fig. 16 is a sketch of a driving airscrew for a rotative winged aircraft proposed in U. S. patent No. 2,301,417 by A. E. Larsen. Instead of the usual rotor tip nozzles, jet driving devices are carried on the tips of outboard airscrews mounted on the rotor blade tips. An engine-driven compressor within the aircraft delivers the propelling fluid through passages to the jet nozzles.

By the use of outboard airscrews the efficiency of the system is contemplated to be greatly improved as the airscrew high r.p.m. is more nearly within the efficiency range of jet propulsion. A rotor blade tip speed of 600 f.p.s. and an airscrew tip speed of approximately 1000 f.p.s. is desired

Illustrated in Fig. 17 is a novel form of aircraft as suggested by H. P. Massey in U. S. patent No. 2,344,515. Air is drawn into a cylinder by the engine driven propeller and after passing through a shaft is discharged through slots for increasing lift. A similar arrangement may be applied to the whirling airfoils of a helicopter. This invention and numerous others relate generally to the lifting of aircraft by the Magnus effect—an effect due to rotating a cylinder in an air current, thereby increasing the velocity of the air current and decreasing the air pressure on the rotating body.

Postwar aerial commercial transports propelled partly or wholly by reaction jets are at present under consideration. A helicopter-flying-wing transport design of E. Burke Wilford is outlined in Fig. 18. Housed in the wing are blowers which drive the single-bladed rotor at high speeds. With the counterbalanced rotor reaching speeds above 500 m.p.h. the effectiveness of jet propulsion becomes apparent. During forward flight standard propellers drive the aircraft while the rotor ceases to function and acts as a stabilizer.

Ryan Fireball Jet Fighter

NEW CARRIER-BASED JET AND PROPELLER PLANE

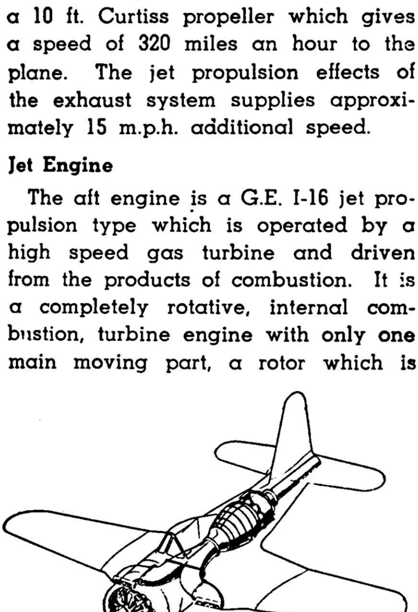
First successful plane in the United States to combine jet propulsion with a conventional engine and propeller is the Ryan Fr-1 Fireball fighter produced by the Ryan Aeronautical Company, San Diego, Cal., for the U. S. Navy. The all-metal carrier-based plane mounts a conventional engine in the front and a General Electric thermal jet engine in the rear.

Dimensions of the Fireball are: wing span, 40 ft., length (overall) 32 ft. 1 in., height (to rudder top), 13 ft. 7 5/16 in., height (to propeller blade vertical), 11 ft. 1 in., wing width (folded), 15 ft. 11 in., wing height (folded), 16 ft. 9 in.

The forward engine is a C9HC Wright Cyclone, model 1820-72, nine cylinder, air-cooled radial type. Its rated 2700 r.p.m. with 1350 b.hp. drives a 10 ft. Curtiss propeller which gives a speed of 320 miles an hour to the plane. The jet propulsion effects of the exhaust system supplies approximately 15 m.p.h. additional speed.

Jet Engine

The aft engine is a G.E. I-16 jet propulsion type which is operated by a high speed gas turbine and driven from the products of combustion. It is a completely rotative, internal combustion, turbine engine with only one main moving part, a rotor which is connected by a composite shaft to a centrifugal air compressor.



—Ryan Aeronautical

Diagram of the power plant combination employed in the Fireball.

—Ryan Aeronautical

A jet-pushed, propeller-pulled Ryan Fireball fighter in flight.

Atmospheric air enters the inlet openings located in the wing leading edge, is compressed by the air compressor and discharged at high velocity to ten combustion chambers where it mixes with burning fuel from nozzles. The expanding gases cause the gas turbine to rotate and escape out a rear cone creating propulsive thrust. The turning turbine wheel drives the impeller of the compressor.

The ignition system is used for starting only, as the combustion is self-sustaining. Pumps supply fuel to the combustion chamber, while a governor controls the maximum speed of the aft engine by by-passing the fuel flow. Like all jet planes the efficiency of the jet engine increases with speed. With jet power alone the Fireball does over 300 miles an hour. Peak speed from both engines is still a Navy secret.

The versatile fighter has a high rate of climb, short takeoff, extreme maneuverability, slow landing speed, good combat radius and heavy firepower

A Liquid Propellant Rocket Motor

By LOVELL LAWRENCE, Jr.

The liquid propellant rocket motor develops forward thrust by the rearward expulsion of combustion products at super-sonic velocity. The rocket motor as distinguished from current aircraft powerplants of the jet propulsion or propeller type, does not operate on atmospheric oxygen, but depends upon a supply carried with the motor. The oxygen is furnished by an oxygen-yielding compound, known as the oxidizer, the fuel may be any hydrocarbon, both of these being known as the propellants. The jet reaction engine under consideration utilizes liquids for propellants which are fed into the combustion chamber, and for this reason, its operation cannot be compared to the powder or solid propellant rocket motor whose entire charge of fuel is lodged in the combustion chamber. The liquid propellant motor has been widely developed in both the United States and Germany because it can be repeatedly operated for long periods of time by merely replenishing the propellant supply.

Motor Description

Basically, this rocket motor (Fig. 1) consists of an injector, the counterpart of the reciprocating engine's carburetor, a combustion chamber, nozzle, and cooling jacket.

The injector indicated at No. 1 is made up of two chambers, one to feed the oxidizer into the injector jet, the other to feed the fuel. An igniter or starter not shown here, is usually incorporated in the injector when the propellants used are not spontaneously combustible.

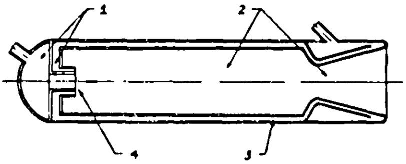


Fig. 1. Liquid propellant regenerative rocket motor.

The combustion chamber and exit nozzle are usually considered as a unit, as shown at No. 2, since the entire combination must be cooled with one of the propellants flowing in the space formed by the outer jacker and baffle, shown in No. 3.

It should be noted that since this cooling arrangement returns the dissipated heat energy to the combustion chamber with the propellant, there are practically no cooling heat rejection losses, thus affording a regenerative powerplant.

After the propellant has traveled up the cooling jacket, it then enters the space at the entrance to the injector jet, and finally enters the combustion chamber impinging on the other propellant which has entered at No. 4. It is possible to use as a coolant, either the oxidizer or the fuel, depending on their characteristics.

Combustion Factors

In the combustion chamber, the fuel and oxidizer are burned, thereby converting thermal energy into high pressure gases which are ejected from the exit nozzle. The exit nozzle changes the internal energy of the rapidly expanding combustion gases into kinetic thrust energy by accelerating the gases to super-sonic velocities as they move from the high pressure region in the combustion chamber to the relatively low pressure region outside the nozzle. Critical fac-

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Presented at the Rocket Dinner of The American Society of Mechanical Engineers, New York, November 26, 1945 tors in nozzle design are the throat area and exit flare, the throat area being the major factor since it controls the rate of ejection of the gases. The exit flare angle is designed to follow the natural expansion of the gases as they pass from the nozzle throat to the atmosphere.

Momentum Equation

The propulsive action of the rocket motor is described by the fundamental impulse momentum equation solved for the resultant force in terms of the change of momentum of the propellants relative to the motor. The thrust force F, is measured in lbs., the propellant mass m, in slugs, the velocity of exhaust gases V, in f.p.s. and the time interval t in seconds. For example, a total mass of propellant consumed at the rate of 8 lbs. per sec. and producing an effective jet velocity of 6600 f.p.s. will deliver a thrust of 640 lbs.

Propellant Consumption

In considering the economy of operation of the liquid propellant rocket motor, it is advisable to keep in mind the distinguishing characteristics of the motor as outlined before. Whereas, fuel consumption is the yardstick of economy of the airstream and internal combustion engines, propellant consumption is the basic measure used for the rocket motor. This factor, naturally, affects the calculation of specific consumption. Instead of computing lbs. of thrust per lb. of fuel per hour, lbs. of thrust per lb. of propellant per hour must be computed.

The efficiency problems of the rocket motor are the same as the conventional propeller type powerplant where the product of the thermal efficiency and propulsive efficiency is equal to the overall efficiency. The thermal efficiency of both powerplants is a function of the available energy for propulsion after the engine has converted the thermal energy of the fuel into output shaft horsepower or exhaust jet energy as the case may be. The propulsive efficiency is a measure of the ability of the propeller or exhaust jet to convert available shaft or combustion energy (respectively) into propulsive effort.

Thermal Efficiency

In practice, the thermal efficiency may be determined by substituting measured thrust and propellant flow rate in the fundamental impulse momentum equation $F = mV/t$ and calculating the effective jet velocity. Then the square of the ratio of effective jet velocity to theoretical jet velocity is the thermal efficiency. The theoretical jet velocity is based on the available b.t.u. content per lb. of propellant mixture. The mixture used in this instance is ethyl alcohol (75%) and liquid oxygen. It is important to note, referring back to the example, that at the present time but 28% of the available b.t.u. content can be turned into effective energy because of the molecular dissociation and cooling problem at high combustion chamber temperatures. The thermal efficiency does not change with the velocity of the rocket but does improve with increasing altitude because of reduced atmospheric back pressure.

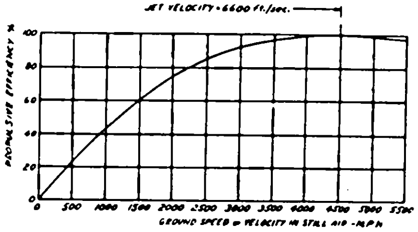


Fig. 2. Propulsive efficiency vs. speed.

Propulsive Efficiency

The propulsive efficiency is a function of the thrust, the velocity of the rocket relative to the ground, the net thermal energy, and the kinetic energy of the propellants by virtue of their motion relative to the ground. Fig. 2 shows a graph of the propulsive efficiency versus the ground speed of a rocket for a jet velocity of 6600 f.p.s. (4500 m. p. h.). As the ground speed approaches the velocity of the jet, a maximum efficiency of 100% is obtained.

Overall Efficiency

Fig 3 shows a comparison of the overall efficiency versus speed for a conventional engine with propeller as compared with a liquid propellant rocket motor. The efficiency scale is the same for both. The velocity scale of the rocket motor is ten times that of the reciprocating engine. Surprisingly enough, the rocket motor has a better overall efficiency than the best efficiency of the conventional type when it is operated in the proper speed range near its exhaust jet velocity. This is possible because 100% propulsive efficiency is obtainable for the rocket where the airplane propeller utilizes about 80% of the available shaft power. Since the rocket motor has a 25% efficiency at 2750 m.p.h., it can get the same mileage per lb. of propellant mixture as the conventional engine's mileage per lb. of fuel at 350 m.p.h. Therefore, the rocket can travel the same distance in about 10% of the time.

There are, of course, many other variables affecting the picture of reaction propulsion but it is desirable to indicate the main potentialities in the light of present misconceptions of the operating efficiency of the rocket motor.

Since the development of this form of propulsion is only on the threshold of extensive progress, it is reasonable to assume that greater efficiencies than 28% will be obtained in the near future.

Now consider a 1500 lb. thrust unit performing on a test stand. This 25 lb. unit compares with a 1000 hp. aircraft engine. The peculiar beaded nature of the exhaust flame is caused by the reflection of the burning gases from the relatively motionless surrounding envelope of air. Since the jet stream is traveling at about six times the speed of sound in the adjacent air, the air is unable to compress rapidly enough and in effect forms a "solid" cylindrical tube through which the exhaust gases move. Eventually, friction slows the outer layers of the flame column down and air mixes with it causing the conical taper at the end of the flame.

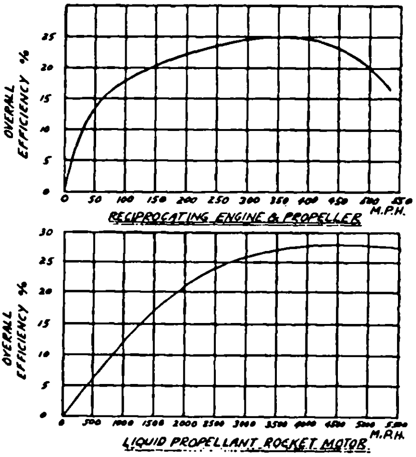


Fig. 3 Comparison of overall efficiency of a conventional engine with rocket motor.

Assisted Takeoff

The application is the use of the liquid propellant rocket motor for assisting takeoffs of heavily loaded aircraft whose motors are not powerful enough to supply the necessary thrust. This characteristic of the rocket motor is especially useful on water-borne planes and those which operate from airports at high altitudes where air density does not permit proper aspiration of the engines thereby reducing power output.

Small Motor Fuel Injection

Recent Investigation On Sprayer Devices

By DAVID ELLIOTT

In the December 1944 issue of ASTRONAUTICS appeared a drawing of a simple intermittent jet motor with suggestions that experiments could be carried on with this type of motor in spite of wartime shortages. A previously made small stainless steel combustion chamber intended for use in a compressed oxygen-gasoline rocket motor was abandoned because of the risk involved in handling such fuels without proper training. However, this was a good start toward a jet motor, and it was incorporated into a design, similar to the one in ASTRONAUTICS, which was completed last summer.

Motor Description

The conical sheet metal air scoop opened into a tapering steel tube in which was mounted a model airplane engine gas tank and needle valve assembly. Air rushing through this tube was supposed to induce an explosive mixture of gasoline and air which passed into the combustion chamber through a diagonally drilled hole in a rotary valve mounted in the front of the chamber. An air vane turned the rotary valve and a breaker point assembly which fired the spark plug after the valve closed.

The entire motor was mounted outside a window of a motor car to provide it with the necessary forward speed while at the same time being easily accessible. Several attempts were made to run the motor at speeds up to 60 m.p.h., but at no time did any gasoline leave the tank. With the gas tank mounted above the air intake with a gravity feed the gasoline dripped into the intake and slow evaporation caused the motor to run occasionally for brief intervals.

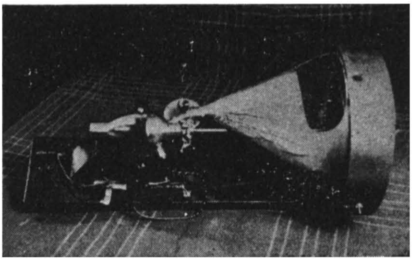
Fuel Sprayers

After several months of experimenting with various types of fuel sprayers the following conclusion was reached which seemed the crux of the entire problem. There are two general methods of spraying gasoline so it will mix with air and produce the explosive mixture necessary for the operation of a jet motor.

The most widely used method of spraying a liquid is to pass a rapidly moving stream of air past an opening in a tube which is connected with a container of the liquid. In accordance with Bernoulli's principle the pressure at this opening is less than the pressure in the container, and consequently the liquid flows through the tube and out into the stream of air where it is broken into a fine spray.

This type of sprayer is used in internal combustion engines, paint sprayers, insecticide sprayers, and similar devices. Since the fluid in passing from the high to low pressure end of the tube must pass through the tube, considerable velocity is produced. In fact, calculations for the velocity of the air leaving an ordinary household insecticide sprayer give results of sev-

(Continued on Page 25)



An experimental intermittent jet motor.

Nozzles

Nozzle-less Devices Defined

By WILLIAM D. MONROE

The present controversy raging over the possibility of nozzle-less jet engines is very simply settled. There are no nozzle-less jet devices for supplying power at the present time. To understand this bold statement one must consider jet devices in the light of an exact definition of nozzles and their functions.

Such a definition may be found in the second edition of Everett's Thermodynamics.*

"A nozzle is a directive channel whose prime function is the conversion of pressure or thermal energy of a fluid to kinetic energy of the issuing stream.'

This is a complicated, but exact way of saying that any channel (convergent, divergent, straight or convergent-divergent) through which fluids expand to convert their heat or pressure energy into velocity in a given direction is a nozzle. Since the mass of gas is given a velocity at the expense of its heat or pressure energy, it is seen that the heat or pressure energy is converted into kinetic energy.

Athodyd Operation

The so-called nozzle-less devices are actually units that combine both the combustion chamber and nozzle into one. The common athodyd as demonstrated for Life magazine** by the General Electric Laboratories in Lynn, Mass., combines the mixing head, combustion chamber, and nozzle into one. The air entering its mouth slows down and expands as it approaches the largest cross-section of the engine about one-third the way back. Air still rushing into the mouth produces a ram effect which greatly increases the pressure at the largest section.

Here also, fuel is injected into the mass and burned. The expanding mass is then directed from the fuel injection point, toward the exhaust port. The engine section between the fuel injection point, the largest section, and the exhaust port may be considered as a combination combustion chamber and a nozzle since the gas burns in this area and the resulting heat energy is converted into kinetic energy because the mass gains velocity while lowering its heat content as it moves toward the rear.

C-P Engine

A similar analysis of the Giles proposed C-P engine reveals that it will break down in the same fashion as the athodyd. Upon reading the more or less unsatisfactory report of the test of this engine* one comes to the conclusion that the main fault of the engine lies in the fact that the fuel mixture was not mixed well enough to allow proper combustion to take place in the interior of the engine. Because the C-P engine is merely a straight bore engine with no contours to mark the various sections its combustion chamber and nozzle may be considered one unit. Indeed, the gases are still burning when they pass through the exit.

After discussing the subject with a layman who "happened to glance into one on Okinawa," and carefully examined a few very unsatisfactory photographs and data, the author has come to the conclusion that the Japan-

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* Everett, H. A., Thermodynamics, D. Van Nostrand Co., page 252.

** Life magazine, Nov. 27, 1944.

* Astronautics, No. 49.

ese Baka Bomb engine uses liquid fuel and its tubes may be similar to the C-P engine. One possibility is that the fuel was discharged through an elongated nozzle, running through the axis of the tube, the nozzle having larger and larger holes at right angles to the axis. Of course the oxygen would be supplied through a modified concentric feed at the extreme rear of the tubes.

Giles Design Standard

An examination of the design criterion laid down by Mr. Giles for a nozzle-less engine reveals the ideal nozzle-less engine to be actually a proposed method of combining the combustion chamber and nozzle into one unit. To quote the third design criterion, "The motor should support, shape, surround and guide the jet," and by implication the fuel mixture should be almost burned before leaving the exhaust. Compare this with Everett's definition of a nozzle to see why the conclusion was reached that the Giles type engine is really one which combines the combustion chamber with the nozzle.

It may be well to add at this point that, ideally, in an engine with a De Laval type nozzle, the fuel would be completely consumed before reaching the nozzle entrance. This is necessary in order to get the maximum efficiency from the nozzle, because these nozzles are not designed to allow for additional heat being liberated after the gas enters it. Further, variations in the fuel and oxygen ratios will adversely effect the efficiency of any properly designed nozzle because they are made to receive gas traveling at a definite velocity and temperature. Variations in the entering velocities and/or temperatures of the gas, due to irregularities in fuel and oxygen ratios, will definitely effect the efficiency of these engines.

Reaction Possibilities

A deeper consideration of Everett's definition of nozzles naturally leads one to the conclusion that nozzle-less jet devices for producing power are impractical. This is true because the only reaction had would be due to the discharge force of the "cold" combustion mixture. Since the combustion and expansion would take place outside of the engine, the expansion would not be so directed as to produce very much thrust. There are those who will question this by citing the engine whose thrust increased after the nozzle burned off. One simple explanation for that is that the majority of the gases may have been consumed in the remaining engine after the nozzle burned off, and also, a scientific examination of the burned off nozzle may reveal it to be so poorly designed as to cause a great amount of turbulence inside the jet proper. Indeed, if an attempt is made to design a nozzle-less engine with a combustion chamber that will burn the majority of the fuel before allowing it to escape, it will be found that the combustion chamber itself will, at least partially, take over the function normally performed by the nozzle. It would, however, do this less efficiently unless newer design methods are developed.

Three Alternatives

This conclusion leaves the nozzle-less advocates with three alternatives. The first is to devote their energies to design combustion chambers that perform as nozzles as well, as in the G. E. athodyd. The second is to seek new methods of shortening the present De Laval type nozzles without sacrificing efficiency. The third alternative is to develop a different type nozzle which is inherently shorter.

In consideration of the second and third alternatives it is well to remember that the German V2 has an extremely short nozzle for the thrust it produces. It would be interesting to the author if data could be got concerning the longitudinal cross-section measurements of this engine as well as data concerning the entering and leaving velocities and temperatures of the jet. With this data one could determine if the Germans have an entirely new type nozzle, have discovered a method of shortening the conventional nozzle without the sacrifice of efficiency, or if they have sacrificed efficiency for weight economy. For similar reasons like data concerning the Me 163 and Baka engines would be of great interest.

The author strongly suspects that the Germans have perfected a new type of nozzle because of observations made during a careful examination of the meager photographs available to him. A study of the few performance figures available on the engine and certain faintly positive indications observed during some crude experiments conducted by him in 1944, cause this belief to be greatly enhanced.

Tulane Theory

To return to the Giles proposed C-P engine before closing, it is noticed that this type of engine may fit into a radical new theory expounded by Captain Roy G. Tulane, in his article "Auxiliary Propellants." The Captain holds that like turbines, there are two basic types of rockets, each type having its own advantages and disadvantages; the reaction rocket and the impulse rocket. By the Captain's implied definition, the Giles type engine would be a reaction rocket, whereas a conventional rocket with a De Laval type nozzle would be an impulse rocket. Although the Captain's theory has much in its favor, the author wishes to caution the reader that the best attitude to assume is the professional one of "prove it." Such a proof would consist of intensified theoretical research in that direction, extensive tests of the various engines in a vacuum surrounded kinematic test stand (not to be confused with the present static test stand as used by the A. R. S. in 1941 test runs), and for reasons too lengthy to discuss here, the plotting of rocket exhaust/velocity ratios versus efficiency.

Summary

In conclusion, the points made in this article are:

(1) True power producing nozzleless jet devices are impractical.

(2) Combustion chambers properly designed to burn the fuel mixture almost entirely in the engine will take over, at least partially, the function of the nozzle.

(3) As a result of the first conclusion, energies should be directed towards (a) designing units combining both combustion chambers and nozzles, and (b) seeking new shorter nozzles, or a practical way to shorten the present ones without sacrificing efficiency.

(4) Jet units of the Giles type may aid in proving or disproving the radical new Tulane theory. Whether or not Captain Tulane's new theory is the expression of providence-guided-brilliance will only be settled by time and hard work.

—British Official Photograph

A twin-jet Royal Air Force Meteor in flight.

An Introduction To Jet Propulsion

By G. EDWARD PENDRAY

It is most necessary, in getting a grasp of the true inwardness and significance of this subject, to take note of two sources of confusion which have in recent months somewhat clouded it. Since about 1941, we have been treated to almost innumerable articles on jet propulsion and its applications, many of them unfortunately written by folk who had had too little time to become fully equipped on the subject. As a result, much of our information from those sources is incomplete and a bit confusing, and needs putting in place.

Adding to this confusion is the fact that during the last four or five years several types of motors and engines have been developed which operate on the general principle of jet propulsion. They have been in the main developed by different groups of engineers, sometimes in different countries, and all prevented by the needs of wartime secrecy from exchanging views, data or language.

Dry Fuel Rocket

Consider the internal construction and the operation of the simplest and best-known of all the jet-propelled devices—the ordinary skyrocket. As shown in Fig. 1 at the top is a cone-shaped hat, (C), filled with black pellets. These are the payload of the skyrocket, for they are the fiery stars which the rocket will eject at the top of its flight, to give the familiar pyrotechnic effect.

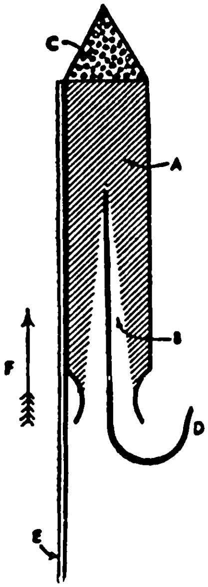

Fig. 1. Cross-section of a skyrocket.

The stars, of course, have nothing to do with propelling the rocket. This is accomplished by the material in the cylindrical portion of the rocket just below (A). The outer case is usually made by soaking pasteboard in glue and water, then rolling it on a mandrel to give it the cylindrical form. Before the material hardens, the lower part is drawn in to provide a crude nozzle.

When the rocket is charged a cone-shaped dibble is driven up through the nozzle and black gunpowder or a similar propellant mixture is packed in all around it, driven hard with the aid of a mallet or hydraulic ram. When the dibble is withdrawn, a cone-shaped cavity (B) remains in the lower part of the charge—a cavity which is sometimes picturesquely referred to as the "soul" of the rocket. The fuse (D), leading in from the outside, ends in this cavity.

When a skyrocket is fired, the sequence of events is as follows. The spark follows the fuse into the cavity,

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Presented at the Rocket Dinner of The American Society of Mechanical Engineers, New York, November 26, 1945.

and ignites the walls of the powder charge. Though the charge usually consists of gunpowder an explosion does not occur because the charge is so tightly packed the flame cannot permeate it, and can only burn, therefore, on the walls of the cavity. As it burns the cavity enlarges rapidly and the fuel is transformed into gas at high temperature and pressure. There is only one place it can escape, and consequently a jet goes roaring out of the nozzle, thrusting the rocket in the opposite direction (F). The attached stick (E) guides the skyrocket straight upward.

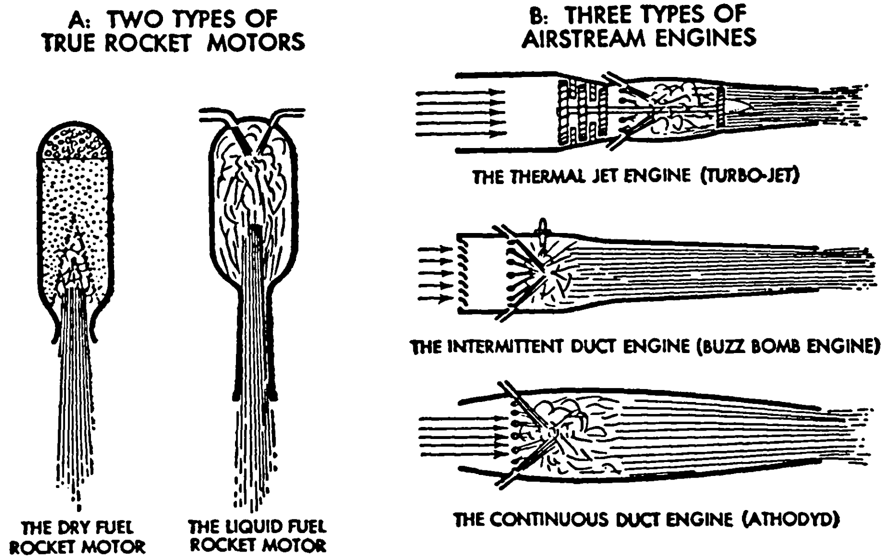


Fig. 2. Schematic drawings of the five types of reaction motors.

Liquid Fuel Motor

In Fig. 2, Part A, is the schematic outline of two kinds of rocket motors. The dry fuel (or solid propellant) motor is at the left. The scheme of the liquid propellant rocket motor is shown at the right. In this design, the propellants are brought in through mixers or inlet ports at the upper part of the combustion chamber and are reacted together in the chamber. The resultant gases jet through the nozzle, providing thrust.

It will be noted at once that the liquid fuel motor, unlike its dry-fuel counterpart, requires the use of separate tanks or containers for the propellants. As a result, the motor can be surprisingly small and light. A motor capable of producing 100 lbs of thrust can be held in the palm of the hand. The German V2 rockets made use of a liquid fuel motor producing 60,000 lbs. of thrust (30 tons), and this entire thrust was produced by a motor a little more than 6 ft. long and weighing about 1,000 lbs.

The rocket motors, because of their simplicity and the furious rate at which they liberate energy, are best suited to the propulsion of rockets—that is to say, projectiles. But there can obviously be another class of jet propulsion devices—usually called the airstream or air jet engines, which are better for the propulsion of aircraft because they can exert steady power over long periods of time, and draw one of the components of their propellants, the oxidizer, from the atmosphere itself.

Thermal Jet Engine

Schematic diagrams of three principal types of airstream engines appear in Fig. 2, Part B.

The one at the top, which is best known, is technically referred to as the thermal jet engine—or more affectionately as the turbo-jet. Air enters this engine through a collecting collar at the left, is compressed by means of a rotary air compressor into a combustion chamber, where fuel is injected into it and burned. The resulting gases, and the large volume of heated unburned air, then pass rapidly out through the nozzle at the right. On the way they are forced to pass through the blades of a gas turbine, which extracts some of the power to operate the rotary air compressor. It will be seen that in this type of device, some of the energy of the jet—as a matter of fact about 2/3 of it—is used to keep the cycle going, and only the remainder is available to provide thrust.

Intermittent Duct Engine

The second type of airstream engine is that in the middle, which is referred to by the British as an intermittent duct engine, and by American engineers as a resojet or a pulsojet. It is also sometimes called a buzzbomb engine, because it was this kind of device that drove the German VI weapons, or buzzbombs.

In this engine the action must be started either by compressed air or by rapid forward motion such as the Germans gave it with their buzzbomb launching ramps. When head pressure reaches a suitable level, the spring-controlled flap valves at the forward end of the tube are blown open and the air enters the combustion chamber, where it is mixed with gasoline and fired. The resulting blast blows the shutters closed. Expansion then forces the gases of combustion and the column of air out the rear, producing a jet. But this leaves an area of low pressure in the chamber, which automatically open the shutters again. More air comes in, and the cycle is repeated.

The rate of the cycle depends on the resonance, and hence on the length of the tube. In the German buzzbomb engine the tube was about 11 ft. long, and the rate of firing about 40 times a second. It is because of this resonance effect that this device has been called the resojet or pulsojet.

The buzzbomb engine, at the present state of its development at least, isn't much of an engine so far as efficiency goes, but it is so light and simple, and so cheap to produce, it may nevertheless have many uses both in war and in peace. It was, of course, well suited to driving the German buzzbomb. The powerplant of the buzzbomb represented only 8 per cent of the total starting weight of the craft, and permitted a payload that represented nearly half the launching weight.

Continuous Duct Engine

The third airstream engine is sometimes referred to as the continuous duct engine, though it is now becoming more familiar under the British name athodyd and the American appelation ramjet. Athodyd incidentally is a classical-sounding title which has been made from the significant letters of the original British descriptive name, aero-thermal-dynamic-duct. Ramjet fits the engine better than any of the other names and is finding increasing favor.

When the ramjet is moving forward (toward the left in the figure) at the speed of sound or thereabout, the air is rammed into the open forward end, expands in the combustion chamber, and is there burned with gasoline or other fuel, to produce an accelerated movement toward the rear and out the nozzle.

Like the rocket motors, the ramjet needs no moving parts whatever for its operation, but it has the peculiarity that it will provide relatively little power until it gets going at speeds near that of sound. Consequently, unlike the turbo-jet, it can hardly serve as a source of primary power for aircraft, though it may well be most useful as a booster engine for high altitude, fast-flying jet-propelled aircraft using turbo-jets as primary power.

Jet Efficiency

The efficiency of jet propulsion motors and engines has been the subject of much discussion, and a good deal of the data that has appeared in print have indicated a low efficiency for jet propulsion, as compared with conventional engines, especially those used in driving the familiar types of aircraft.

While there is no quarrelling with these figures, they often present a somewhat distorted view, arising from the fact that in a real sense jet propulsion and reciprocating engines are not competitors. There is a basic relation between speed and efficiency in all types of jet-driven craft, whether aircraft or rockets. This relation shows that mechanical efficiency, that is, the efficiency of conversion of the jet into forward motion of the driven craft, depends on speed and reaches its maximum value only when the craft is moving at the speed of the jet.

Now, the jet speeds of thermal jet-engines are of the order of 1200 miles an hour, and the jet speeds of the best liquid fuel rocket motors are around 3,500 to 4,000 miles an hour. It is therefore not surprising to find that jet driven planes are large fuel consumers when they move along at only 300 to 400 m.p.h. At the speeds which their engines perform best, but to which as yet no aircraft has been designed to fly, namely at speeds from say 1,000 miles an hour upward, jet driven aircraft will be appreciably more efficient than reciprocating engines, or any engines that make use of a propeller.

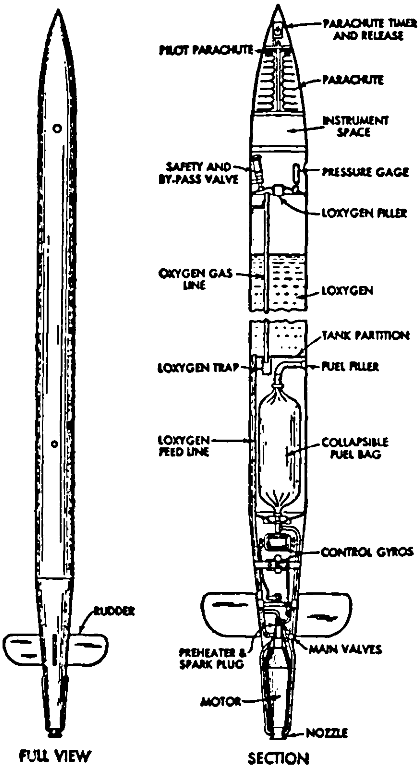


Fig. 3. A proposed sounding rocket.

What jet propulsion offers is a new dimension in velocities, altitudes and horsepower available for flight through air or space. Jet engines for aircraft begin to be effective only at the point where propeller driven aircraft must leave off; that is, at speeds above 450 miles an hour, at altitudes greater than 6 to 8 miles, and at power output per engine from 3,000 hp. up.

Sounding Rockets

Fig. 3 is the schematic design of a sounding rocket intended for vertical flight, carrying instruments. This pre-war design is somewhat out of date now, but will serve nevertheless to show the principal parts of such a rocket—which do not vary appreciably from the long-range trajectory rockets such as the V2, except in size. This rocket was intended to land by parachute and hence it has a parachute compartment at the forward end, right where the warhead was carried in the V2. Just behind this is the payload compartment—where instruments would be carried in a sounding rocket, and where the Germans placed the control instruments used in guiding their V2. What follows, taking up more than two-thirds of the length of the rocket, is the space occupied by the propellant tanks. In this small rocket the fuels were supposed to be forced into the motor by means of gas pressure—more particularly by the pressure of oxygen vapor produced by evaporating some of the liquid oxygen. In the V2—as perhaps will be the case in all such large rockets, the fuels were forced into the motor with the aid of pumps.

In this sounding rocket, which incidentally was designed by James Wyld, president of the American Rocket Society, the control gyro, required to assure vertical flight, was placed just behind the fuel tanks. The motor as in the V2, was located at the rear.

Fuel Importance

This design illustrates clearly the essential simplicity of a liquid fuel rocket, and also makes clear that a major part of the space and starting weight of any long-range rocket, whether intended for vertical or trajectory flight, must be given to fuel. As a matter of fact, the fuel-weight ratio is of extreme importance. For major distance it must be such that the total weight of the fuels at the starting amount to at least two-thirds of the starting mass.

It follows, from the nature of trajectory flight, that all of this fuel must be burned rapidly to transform in the shortest practical time the chemical energy of the fuel into kinetic energy of the rocket. The limiting factor on the rate at which the fuel can be burned is the resistance of the air. The rate of acceleration of the rocket must be so regulated that the rocket will not reach too great a velocity too low in the atmosphere, or else head resistance will rob it of too much power.

Calculations of the rate of fire, therefore, is a complicated matter. At the risk of making it too simple, it can be said that the average rate of acceleration for a long-range liquid-fuel rocket will be of the order of three times gravity. The German V2 started with an acceleration of about 2½ g, and ended its powered flight with an acceleration of about 5 g.

Rocket Trajectory

The trajectory of a typical long-range rocket has four main parts (Fig.

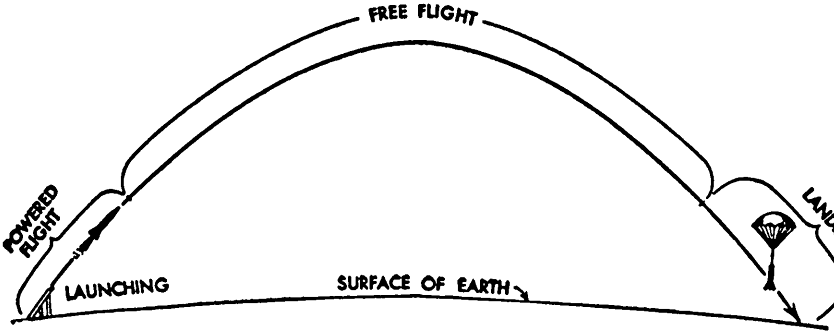


Fig. 4 Rocket trajectory, showing the four parts.

4). There is, first, the launching, which is relatively brief and may consist, as in the case of the V2 of nothing but a short vertical flight to clear the ground before the trajectory control instruments were ready to take over.

There is next the highly important period of powered flight, during which the entire fuel supply is burned to give the rocket momentum. In most rockets this is a relatively short period. In the case of the bazooka it is less than 1/10 of a second. In the German V2 it was between 60 and 70 seconds—during which the motor burned about 12 tons of propellants.

Free Flight

By far the longest part of a rocket's flight is the free flight, which begins the moment the fuel is shut off or consumed, and lasts until the landing gear, if any, takes over for the final phase of the shot. The V2 had a free flight of about 4 minutes, during which time it passed over from Holland to London, a distance of about 200 miles. At the highest part of the flight the V2 was about 60 miles above the ground.

In order to permit this rocket to travel such a distance in free flight, the V2 motor had to give it a velocity at the end of powered flight of better than 5,000 f.p.s. (about 3500 m.p.h.), and the control gyros had to manage the flight that the angle of the rocket's motion relative to the earth at the end of powered flight was almost exactly 45 degrees.

Obviously, there is much more to a long-distance rocket than meet the eye. So new is this field that almost any direction is barbed and shadowed with unknowns. The field of the liquid-fuel rocket is certainly one of the most exciting new areas in all mechanical engineering.

ROCKETRY NEWS

Jet Buzzbomb

Northrup Aircraft reveals that its buzzbomb, the JB1A, has a 30 ft. wing span and weighs 7,000 lbs., including 3,700 lbs. of explosives housed within the wings. In production since the summer of 1944, the reducing of the length of the launching tracks to 50 ft. now permits its use on landing craft. Aided by four rockets, the JB1A is catapulted from a 14 ft. aluminum tube on a launching sled at over 220 m.p.h. An earlier twin-jet aircraft, built by the company, was patterned after its flying wing and carried bombs on the sides of the engine.

Jet-Propelled Fireboats

The Coast Guard during the war operated a number of water-jet-propelled fireboats for port security work. The 30 ft. highly maneuverable boats drew in water by centrifugal pumps and discharged it through an underwater T-shaped 3 in. propulsion tube at the stern. Operation of a three-place valve in the tube enabled the boat to attain a top speed of over 7 knots forward or to back up.

1,400 M.P.H. Device

Curtiss-Wright Corp. has announced that it has developed controlled, self-sustaining flying devices capable of exceeding 1,400 miles an hour—double the speed of sound. All details were withheld except that the special devices were not rockets or artillery shells, and at present are pilotless.

Zero-Length Projectors

Post type launchers consisting of front and rear parallel located studs are replacing old type long-length tube-clusters and rails to support rockets under the wings of aircraft. Rockets, when fired, only need to travel about one inch before being released entirely from fittings.

Rocket Tracking By Radar

A Method Of Strengthening The Radar Echo

By GENE R. BUSSEY

The ordinary experimental rocket, through metallic, is too small to give a satisfactory radar "echo" at any appreciable distance using existing radars. The solution to this problem is to have the rocket carry an auxiliary device, the purpose of which will be the artificial strengthening of the radar echo.

Such a device already exists. It consists of three main units which together comprise a "transponder." A receiver detects the radar pulses; these pulses are amplified and shaped in a keyer, which in turn—simultaneously with each pulse—keys a transmitter oscillating at the radar frequency. The resulting pulses of energy reinforce the echo pulses. The result on the radar screen is a strong dependable indication even at a considerable range.

IFF Equipment

This principle was used widely during the war in IFF (Identification, Friend or Foe) equipment. In practice the reinforcing pulses were varied in such a way as to "code" the returns, thus making it difficult for the enemy to simulate the device for deceptive purposes, but for rocket tracking purposes the coding feature is of course superfluous.

Aside from its identification purposes, IFF equipment made it possible to follow friendly planes when the radar unassisted could no longer register an echo. Planes have been tracked for a hundred miles after their echoes had faded from the screen simply by observing IFF returns.

Range Limits

The range limit for existing equipments is an unknown quantity. Satisfactory results in excess of 500 miles and probably 1000 miles are immediately possible in the absence of shadowing effects due to the earth's curvature—which situation would obtain in the case of a rocket fired vertically. The ionosphere, which reflects communication frequencies, would be no barrier whatsoever at ordinary radar frequencies.

Transponders

Existing transponders are small and light. It is safe to say that an existing IFF equipment can be stripped of its coding mechanism and other unnecessary items so that its weight, complete with batteries, will be less than ten pounds.

When very accurate ranges are desired, the slight time delay of the transponder must be taken into consideration. But this delay is constant with distance and is therefore easily compensated for.

Radar Tracking

Without divulging any secret information, here is a sketch of what can be done with existing equipment used for rocket tracking purposes. When the rocket is fired, radars will follow it in azimuth, elevation and range. Automatic plots of this data will be recorded. The resulting graphs will show the rocket's velocity, acceleration and distance at any instant; when it runs out of fuel; when it reaches maximum elevation; and how it falls back to the earth. Mathematical analysis of these graphs will divulge the actual atmospheric drag throughout the gamut of the rocket's velocity.

The Cuxhaven V2 Tests

British Scientists Fire Long-Range Rockets

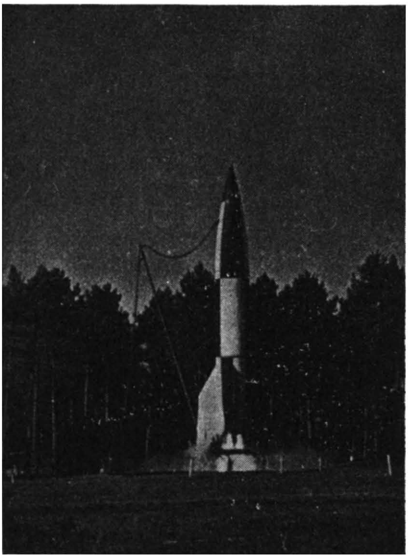
By E. BURGESS

In early October 1945, British technicians under the supervision of Sir Alwyn Crow of the Ministry of Supply, working in collaboration with German scientists, fired two V2 long-range rockets which had been assembled from parts cast aside by the Germans.

The firings took place from Cuxhaven and the rockets were painted black and white so that observation of their flight would be facilitated. Transported in a horizontal position on special trailers to the launching site the rockets were raised into the vertical firing position by a launching cradle and the control apparatus was then tested. The various liquid fuels were brought in special mobile bowzers from which they were pumped into the rocket. Ethyl alcohol, hydrogen peroxide, liquid oxygen and calcium permanganate were loaded into the fuel tanks in that order, the process taking about twelve minutes to complete. Then the feeding and testing connections were removed leaving just a single light cable, attached to the control compartment of the missile and supported on a long slender pole, as the only connection between rocket and ground controller. The V2 was ready to be launched.

—British Official Photo

The Cuxhaven V2 test rocket in the vertical firing position surrounded by fuel lorries.



—British Official Photo.

V2 rocket at moment of takeoff.

Launching Technique

An igniting torch, similar to the fuses of the early A. R. S. experiments, was then ignited and the main fuel valves were opened. The effects of gravity caused liquid oxygen and alcohol to feed through the fuel-feed system into the motor, which thus commenced to fire but only developed

—British Official Photo.

As the V2 speeds upward forty feet from the ground, aimed at a target 150 miles away.

about four tons thrust. This warmed up the motor and enabled the operator to ascertain that all the equipment was functioning correctly before the full launching thrust of 26 tons was employed. An electrical circuit, completed through the remaining cable, enabled the operator to open the valves for the hydrogen-peroxide and calcium permanganate. Under nitrogen pressure these fluids were fed to the pumping system and upon combination produced the gases for driving the turbine. The main fuel pumps started to operate, forcing the oxygen and alcohol into the combustion chamber at the rate of over two and a half hundredweights per second. At the same time, the cable was released from the upper part of the rocket.

A deeper note issued from the motor. The exhaust gases emerged in a billow of brilliant flame which spread out from the base of the rocket. Immediately the 45 ft. long, 12½ ton metal giant raised itself slowly on a hundred foot length of searing flame, which flickered at its extremity like that of an oxy-acetylene torch.

Flight Characteristics

No rotation of the rocket appeared during the early stages of the flight. The V2 was remarkably stable in flight and there was no "hunting" of the rocket as it progressed upwards. It was, indeed, lifted as though guided by rails, like a lift in a transparent building. Gradually the velocity increased under the acceleration of just over 1½ times that of gravity until the rocket appeared as a mere point of light in the sky.

In the early part of the flight, no trail was left by the rocket, but one did appear later as high altitudes were reached. The point about this high altitude trail was that it was irregular as though the rocket had oscillated in flight. This may have been due to the pitch oscillations which develop after the period of powered flight and which were mentioned in a recent paper by W. G. A. Perring.*

The aiming point for the two missiles was 150 miles away in the North Sea, and they were reported to have landed within three miles of the target. These results rather discount the reports and propaganda statements regarding the "inaccuracy of these erratic terror weapons," and indeed, it has now been revealed that both the United States and Britain have set up research stations for the development of long-range rockets.

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* A Critical Review of German Long-Range Rocket Development, by W. G. A. Perring.

Heinkel Jatos

German Jet Assisted Takeoff Units

By R. D. WOLCOTT, Sr.

The following general description contains information in regard to a specific type of JATO unit employed by the Luftwaffe on aircraft of three general classes or types: fighters, medium bombers and heavy bombers. By the utilization of the JATO units these aircraft could be used on normal field conditions with extreme overloads.

All units examined bore the trade mark of Ernst Heinkel. Construction of one medium bomber unit was started in March 1941 and finished in June 1942. The examination was in part very inaccurate since no material was on hand to conduct a precise investigation.

The smallest unit was designed for use on small aircraft probably fighters or fighter bombers. This unit was approximately 5 ft. in length and at the most 12 in. in diameter. The major difference between this model and the other larger units being an offset thrust line. The thrust line being directed downward at an angle at the throat of the jet. The two larger units had a line of thrust concentric with the center line of the nacelle.

Medium Bomber Unit

The following description is of the medium bomber class and contains identical components of both the fighter and heavy bomber classes, the only difference being slight and generally in size and arrangement suited best to the space at hand. The reactive results are conceded to be directly proportional to the size.

The medium size unit consisted of a nacelle which was mounted to the underside of the aircraft's wing or as in some cases (Ju 287) directly under existing power units. The unit was jettisonable and was connected to the aircraft with an electrical cable which supplied the necessary voltage to operate the compression mechanism.

Overall dimensions of the nacelle for the medium size are 55½ in. long and 27 in. in diameter. Contained within the nacelle is a steel dome 24 in. in diam. This dome is directly connected to the combustion chamber. Fuel (alcohol) is admitted to the combustion chamber under pressure derived from the use of oxygen, and simultaneously oxygen is admitted to the combustion cycle as a component member affecting combustion. The use of a by-pass arrangement permitted the latter.

Combustion Chamber

The combustion chamber mounts directly to the dome and is approximately 28 in. long; this length includes the throat and jet orifice. Oxygen is supplied by five bottles located in the area where the combustion chamber is mounted. Each of the five bottles is attached to a segment ring aft of the steel dome. Included in the area with the oxygen bottles is a tank of light construction marked with a color code of "Orchid" and the letter "Z," the contents of which are unknown but believed to be hydrogen.

The basic assumption of this fact is derived from the close association of the atomic values of the fuels. To anyone familiar with atomic physics the "Z" element is usually derived by table. The only element with values suitable to the circumstances is hydrogen with an atomic number of 1 (unity). The correct mixture of the fuels would appear to be in per cent, alcohol 17.4, hydrogen 16.25 and the remainder 66.35 in oxygen.

Combustion, however, is dependent on the "Z" element in the following manner; fuel is admitted at high pressure and at a high velocity through a very small jet to the forward section of the combustion chamber. There it is deflected by a cone and at the same instant is met by the "Z" element producing the explosion. The following combustion passes to the rear around a spiral vane which tends to increase the mixing and combustive qualities and from there it reaches the throat of the jet itself. The resulting reactive force of the expanding mass of the gases produce the jet thrust. The orifice of the main injector is only 2.6 mm. in diameter and has a very high pressure loading to prevent flash in combustion.

Oxygen Pressure

Simultaneously with these operations the pressure of both free and pressurized oxygen is indicated on two gauges indicating "Forced" pressure at a maximum of 150 "At," and "Free" pressure at a maximum of 33 "At." The compression being derived by an electro-magnetic rotary compressor; this supplements the normal oxygen pressure in the fuel dome. There are five valves used in these various lines to provide the proper pressure and mixture.

The heavy bomber size is much larger than this unit and is approximately 7 ft. long and 4 ft. in diameter. The thrust line is similar to the medium size. The units compare with Allied JATO units and are of very high caliber construction.

(Continued from Page 11)

eral hundred miles per hour, although this is undoubtedly much higher than the actual speed. However, every indication is that the air velocity required to operate this type of sprayer is considerably greater than the velocity at which a small jet motor should move for practical use as a means of propulsion for model airplanes.

In the second type of sprayer liquid is forced under pressure through a nozzle. A widely used type of nozzle is one in which the liquid is rapidly rotated and passed through a hole; the centrifugal force of the rotating stream then causes it to fly apart into a spray. Several constructed large nozzles of this type worked well, but the comparatively small amount of fuel used in a jet motor and the high pressure required to spray it needs an extremely small nozzle with a hole only a few thousands of an inch in diameter. The difficulty of making good fuel whirls this small and the decrease in centrifugal force resulting from the smaller diameter of the rotating stream made the small nozzles unsuccessful.

Future Developments

The type of nozzle finally found most practical shoots two very fine streams of liquid directly at each other; when the streams meet they break into a finely divided mist. A second intermittent jet motor now being built with this method of fuel injection and other improvements will have the r.p.m. of the valve motor, proportions of the valve, and the rate of fuel injection so arranged that:

(1) Length of time valve is closed equals length of time for the combustion chamber full of fuel to burn and expand back to atmospheric pressure.

(2) Enough gasoline is injected into the mixing chamber while the valve is closed to provide correct mixture for the next combustion.

(3) Valve is open long enough for the mixture to pass from the mixing chamber into the combustion chamber at some given forward speed such as 20 m.p.h.

The Rockets' Red Glare

Historical Events In The War Of 1812

By ROBERT WAUCHOPE BASS

Today there is great interest and excitement over the use of rockets, and to many they have seemed a wonderful yet fearful weapon. Rockets, however, are by no means a new weapon, having often been used before, especially during the latter phases of the Napoleonic wars and during the American War of 1812. And after the bombardment of Fort McHenry on September 13, 1814, their use was immortalized by Francis Scott Key.

In the War of 1812 commerce-raiding privateers sailing from the port of Baltimore played a major role, and for the purpose of destroying these privateers the British sent a strong naval squadron, commanded by Admiral Sir George Cockburn, to the Chesapeake Bay in early 1813. The next year, as a result of the ending of the war with Napoleon, England, then having a navy which compared to the other navies of the world as our American Navy does today, reinforced this fleet with formidable units.

Rocket-Firing Craft

These reinforcements included transports loaded with marines, infantrymen, artillery, and a detachment of soldiers armed with rockets. They included at least one rocket-firing ship, the Erebus, and material for equipping rocket boats and barges, forerunners of our modern little "zoom boats."

The British used these rocket-firing craft in all of the engagements on the Chesapeake. At the battle for Havre de Grace, May 3, 1813, the local militia was thrown into confusion by Congreve rockets fired from advancing British barges, and when one of the militiamen, named Webster, was killed by a rocket, it proved the signal for a general retreat.

During his ascent of the Chesapeake, on June 8, 1814, Admiral Cockburn encountered a flotilla of gunboats under Commodore Joshua Barney. Cockburn's squadron contained one rocket boat and a score of barges armed with rockets, "which," reported Commodore Barney, "they were able to throw to a much greater distance than the shot of the flotilla would reach... One of the enemy's rockets fell on board one of our barges, and, after passing through one of the men, set the barge on fire . . ."

A corps armed with rockets was next employed at the Battle of Bladensburg, a British chaplain writing that they "proved of striking utility," and the Americans admitting that "the Congreve rockets of the British proved very much more effective" than their musket fire. In fact, they were so effective that two regiments soon fled in panic, and thus the British rockets were directly responsible for the seizure and burning of Washington that followed.

Bombardment Of Fort McHenry

But the British were still feeling the sting of the "hornet's nest"—Baltimore—which had equipped and sent out more privateers to harass them than any other city in America. They determined to capture the city, and on September 11, 1814, anchored off North Point. An expedition landed at three o'clock the next morning, including a corps equipped to fire rockets, but it was unable to reach Baltimore.

Meantime, at daybreak of Tuesday, September 13, the fleet began bombardment of Fort McHenry. At 3 p.m. three mortar barges and the rocket ship Erebus stood in towards the fort, evidently thinking the defenders were in a state of confusion, since they were then in range of the American guns. But the Americans immediately opened a brisk fire on these attacking vessels, and the British sent a division of boats to tow the Erebus out of range. At midnight five bomb barges and the rocket ship started up the main branch of the Patapsco River, but were discovered and fired on from the small fortifications of Fort Babcock and Fort Covington. At three o'clock in the morning the barges and the Erebus retreated, firing rockets behind them, while the Americans directed their guns by the blazes of these same rockets.

Francis Scott Key, an American poet-lawyer held aboard one of the British vessels, watched through the night to see if that "star spangled banner" over Fort McHenry still flew—

"And the rockets' red glare, the bombs
bursting in air
Gave proof through the night that our
flag was still there."

THE EREBUS

The Erebus, a twenty-gun sloop, was converted by the rocket inventor, Sir William Congreve, into a specialized rocket ship for attacking enemy vessels and fortifications. Some twenty long boxed frames extended from square openings, known as "scuttles," cut in the side of the ship into the hole. These boxes served to protect the interior of the ship from flying sparks and flames, and could be raised or lowered at will. Within the boxes were large-size metal discharger tubes somewhat similar to the type used by British rocket land troops. Lanyards fastened to the tubes were used to discharge the rockets.

The hollow warheads of the large 32 lb. rockets could hold a 24 lb. solid shot, an explosive shell or such incendiary mixtures as pitch, saltpeter, sulphur and powder. A long side stick attached to the rockets guided them in flight.

The Erebus was capable of launching a rocket broadside horizontally or at any angle up to the vertical in a shorter time than required to fire ordinary cannon. Sir William Congreve at that time stated that a rocket ship, such as the Erebus, was equal in firepower to a fleet of ten conventional mortar ships.

The Trend of Rocketry

Rocketry may chronologically be separated into a number of periods or tides during its development. The first period, distinguished by the "fire-arrow" and "Greek fire," appeared from 1200 to 1500 A.D. The second or Congreve era began around 1800, and the present scientific tide started with Goddard's experiments in 1919. At the moment a fourth era seems likely to begin with the launching of the first interplanetary rocket into space.

Predicting the trend of rocketry in the peace following the late war can be of only an exploratory nature. Practical development of the rocket, the jet plane, the many types of jet driven missiles, and the advent of nuclear power to high efficiency with the embodiment of vital warfare improvements will expedite the possibility of achieving and broadening the present aims of rocket technicists.

Although the direction that jet propulsion may take in the postwar picture can be only generalized, that trend is now occupying the attention of an ever-increasing number of readers of the JOURNAL.

Various viewpoints on the subject will be presented in the JOURNAL from time to time.

A Survey Of Spatial Problems

Some Tentative Solutions In Space Travel

By HERBERT RADD

As far as present knowledge is concerned, the only type of acceleration possible in a vacuum is through the use of reaction. This may be achieved by several different methods, e.g., exothermic chemical reactions resulting in the formation of large volumes of gases and releasing these gases through a constricted orifice. However, since the gas velocity would approach below five m.p.s. for our most powerful fuels the mass ejection would necessarily be enormous to move a sizable object. Of course a vehicle utilizing these fuels could travel relatively great distances, but minute in comparison to interplanetary gaps. Here then, is a tremendous problem, a problem which may be solved in two ways:

1. Discover more powerful fuels.
2. Await the practical utilization of atomic energy.

Both of these solutions are speculative and uncertain of achieving immediate successful results. But there is one other possibility which is generally overlooked. This contingency is logical since the obvious tendency is towards a maximum velocity with a minimum of mass loss.

Atom Smashers

In the two atom smashing machines, the betatron and the cyclotron, charged particles are accelerated by means of electrical fields in certain positions (a magnetic field is maintained in the cyclotron to lend a compact circular motion to the movement of the particle). This has also been accomplished with linear accelerators (electrostatic generators) where particles travel in a straight line motion. Electric bullets have been shot at velocities of thousands of m.p.s. While the output of mass at these velocities was exceedingly small in the experiments, it is certain the output can be increased enormously with sufficient experimentation.

Consider an engine of 1 lb. mass output per second at 1000 m.p.s. Some 5.28 x 10 to the 6th power ft. lbs. of reaction energy is obtained. Of course the explanation of the engine has been vastly simplified, and the output treated optimistically, but the mechanism is plausible; it will operate in a vacuum and the expenditure of mass through ejection would be reasonable. The remaining difficulties are all extremely complicated, technical items, which are the major handicaps in this struggle.

The Ion Engine

Here is a more involved description of the tentative engine of the personally named "ion rocket."

An easily vaporized metal, e.g. zinc, is melted and vaporized in a specially designed apparatus and the gas passed through a powerful ultra-violet or X-ray beam, producing a high concentration of metallic ions. These are immediately attracted by intense electrical or magnetic fields spaced regularly in a long tube. Their path is guided by magnetic fields placed to concentrate the beam. With sufficient experimentation a reaction engine similar to the one described can no doubt be built successfully.

A question is immediately raised. Where will all the electrical energy necessary for its operation be obtained? Storage batteries are out of question. Power plants utilizing gasoline are only a more complicated version of the thermal jet engines. But by tapping the source of most of our energy, the sun, an inexhaustable store of energy becomes available.

Sun Energy

There are several ways of obtaining the sun's energy in a practical form:

(1) The photo-electric effect. This method is the most desirable and also the most difficult. Present day photo-sensitive cells suffer from inefficiency, fatigue from light exposure, and painstaking care in manufacture. Minimum requirements of a photo-sensitive surface would be: (a) easy production of surface; (b) reasonable efficiency in all the spectrum from infra-red to short ultra-violet, which probably occurs above the atmosphere. (Relatively very little is known of the shielding effects of the atmosphere); (c) no danger from fatigue since the success of the journey hinges entirely on the conversion surfaces of the vehicle.

(2) Chemical or physical changes produced by light (particularly ultra-violet). These reactions must be cyclic since large amounts of chemicals can not be carried, e.g., oxygen is converted to ozone by wavelengths less than 2200 Angstroms and proper reconversion would result in O_2 and electrical energy. There are other processes which in time may be found to be far better. However, we do have two sound methods of sun energy utilization which are infallible but are questionable as far as serving the purpose.

Spatial Problems

On delving into this subject problems of all categories present themselves: chemical, electrical, mechanical, biological, etc. Assuming the engine and its power source completed seemingly minor problems become major in reality. A partial but well known list is:

(1) Construction of the spaceship. Size, shape, material used and cost.

(2) Air supply. This can be accomplished by large leafed plants which could not only supply continual O_2 but would also remove plant nutrients from human excretions.

(3) Gravity. An artificial gravity must be maintained, probably through the application of centrifugal force. Any dizziness would be purely psychological, since the circular motion would only be relative to the surrounding bodies (planets or stars).

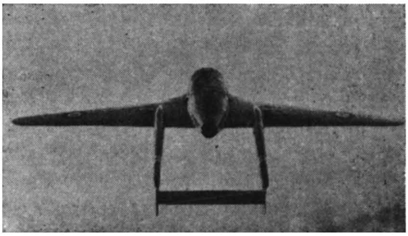
(4) Radar equipment. To detect meteors, asteroids, etc., and automatic integrators to determine velocity, size and direction of travel in relation to the spaceship.

(5) Space suits. For emergency work on the outside of the ship.

(6) Radiation effects. This is certainly a vital question but which can only by answered when sounding rockets penetrate the atmosphere. It may prove to be the enigma of the entire struggle for space travel.

(7) Three dimensional coordinate system for spatial navigation. Probably a great expansion of present day air navigation.

Other walls of difficulties shall place themselves in the path of progress, but with an inevitability comparable to life and death, science will hurdle these impedances until we finally reach the greatest of all man's goals: The Conquest of Space.



—British Official Photograph

Back view of the British Vampire

Society Affiliates With A. S. M. E.

Offices To Be In Engineering Societies Building

Following an affirmative vote of the Active Members, the American Rocket Society on December 1, 1945, became affiliated with The American Society of Mechanical Engineers.

This momentous forward step, which provides many important advantages for the American Rocket Society, does not in any way affect the individuality of the Society or control over its own affairs. The American Rocket Society continues to function as before, with its own independent officers, membership, treasury, publications and meetings.

One result, however, is that the Society will be provided office space in the Engineering Societies Building, 29 West 39th Street, New York, at nominal rental; and after January 2, 1946, A.R.S. headquarters will be located in Room 617 at that address.

Affiliation with the A.S.M.E. has been under study by the Board of Directors for several months. Last summer a three-man committee, consisting of Messrs, Lovell Lawrence, Jr., John Shesta and G. Edward Pendray was appointed to meet with a similar three-man committee of the A.S.M.E. to explore the matter to its conclusion. The joint Committee at length decided that the proposed affiliation would be beneficial to both organizations and to the advancement of engineering, and it stated these conclusions in the following resolution:

"Whereas, it is the purpose and objective of the American Rocket Society, Inc. to further the development of rockets and jet propulsion by the dissemination of technical information through the medium of meetings and publications and by other suitable methods, and

"Whereas, these objectives are consonant with the aims and objectives of The American Society of Mechanical Engineers in the furtherance and development of all phases of Mechanical Engineering, and

"Whereas, it would seem to be of mutual advantage in bringing about the furtherance of these objectives to form an affiliation of these two Societies for the purpose of conducting joint meetings and engaging in other activities of mutual benefit, such as research, standardization, joint publication, etc.

"Now be it

Resolved: That the American Rocket Society, Inc., and The American Society of Mechanical Engineers agree to enter into such an affiliation, subject to the Constitution and By-Laws of each Organization, for a period of five years, with the understanding that the agreement may be terminated at any time by sixty days' written notice from the governing body of either group. This agreement will be in force at such time as it has been properly ratified by both organizations.

"Such detailed agreements as will be necessary for a practical working of the general principles stated above, shall be worked out by a committee made up of three members appointed by each Society and subject to the governing body of each organization.

The American Society of
Mechanical Engineers
L. N. Rowley, Jr.
R. F. Gagg
R. Thomas Sawyer

American Rocket Society, Inc.
Lovell Lawrence, Jr.
G. Edward Pendray
John Shesta"

Following this step the A.S.M.E. submitted the proposed plan to its Executive Committee, and the plan was adopted.

The Board of Directors of the A.R.S. also voted to accept the plan, **subject to ratification by a majority vote of the Active Members of the Society whose votes were received on or before November 19, 1945.**

Of the 82 Active Members eligible to vote, ballots were received from 52. All of these ballots were in the affirmative except three.

On the eve of the 66th Annual Meeting of the A.S.M.E., November 25, the affiliation was jointly announced. A "rocket dinner", held the following night to mark the alliance, was attended by representatives of the A.R.S.

Advantages Of The Plan.

The A.S.M.E. is the largest engineering society in the United States. It is one of the four Founder Societies of the Engineering Foundation which owns the Engineering Societies Building at 29 West 39th Street, New York, where the A.R.S. usually holds its New York meetings.

It is one of the purposes and functions of the A.S.M.E. to aid and foster such special engineering societies as ours, with a view to promoting more rapid technical development of the mechanical arts. The affiliation will make it possible for the A.R.S. and its members to obtain many benefits from the A.S.M.E. not otherwise available, including the following:

1. Immediate added engineering prestige.

2. The likelihood of rapidly increased membership through the attention we will receive among present members of the A.S.M.E. and others. (The A.S.M.E. has 18,453 members, in 70 Sections in cities throughout the country.)

3. Access by A.R.S. members to the famous Engineering Library of the A.S.M.E. in the Engineering Societies Building.

4. Contact with the 70 Sections of the A.S.M.E. for increasing interest among technical men in rockets and jet propulsion, and for possible formation of Sections of the A.R.S. throughout the United States.

5. Members of the A.R.S. may attend meetings of the A.S.M.E., whether or not they are members of the A.S.M.E. (A.S.M.E. members may also attend our meetings.)

6. Joint meetings and programs with the A.S.M.E. for mutual information and the information of members. (These will be in addition to the regular A.R.S. meetings, which are being resumed this year.)

7. Technical assistance (if we desire it) in improving our publications, including the JOURNAL and other publications to be issued by the A.R.S.

8. Office and library space in the centrally-located Engineering Societies Building.

The Society is making great strides these days. Its membership is increasing rapidly and it is steadily growing in importance as an engineering group. Upon affiliation with the A.S.M.E. it takes another major upward step.

G. Edward Pendray,
Secretary

British Interplanetary Society Limited

The Combined British Astronautical Societies and the British Interplanetary Society are voluntarily winding up their societies in preparation to forming a new organization under the name of the British Interplanetary Society Limited. The new national astronautical and interplanetary society will commence its activities early in 1946.

BOOK REVIEWS

Spacewards, Official Organ of the Combined British Astronautical Societies. Vol. 6, No. 3, April-July 1945; 24 pages, 1s.

Editorial comment comprises of a summary of an address at a June meeting on coalition of the C.B.A.S. with the British Interplanetary Society. Technical articles deal with the space position indicator, the uselessness of a spaceship compass, and an electronic spacial rocket article reprinted from ASTRONAUTICS. Lengthy reviews are given on "The Coming Age of Rocket Power," by G. Edward Pendray and "Rockets, New Trail to Empire," by R. L. Farnsworth. Two Northern Branch general meetings, and one each of the Midlands and Southern Groups are reported on.

Rocket-Jet Flying, Pen-Ink Publishing Co., New York. Vol. 101, Fall Edition 1945; 24 pages, $0.75.

The editor of this new magazine, C. P. Lent, author of the book "Rocket Research," presents a general article on rocket development especially considering the V1 robot bomb, V2 long range rocket and the jet plane. Other articles pertain to the bazooka, hints to rocket experimenters, the atom bomb, underground parking for motorcars, and a house car for traveling. The publication is profusely illustrated with drawings and photographs.

Northrup Flying Wing

The revolutionary Northrup Flying Wing now under development will undoubtedly use a combination of conventional propellers and jet units for propulsion. Very likely the gas turbine engines will be arranged to either drive propellers and generate jet propulsion individually or combined.

UNITED STATES PATENTS

The following patents were compiled from issues of the Official Gazette of the U. S. Patent Office. Copies of patents may be obtained from the Commissioner of Patents, Washington, D.C., for ten cents each.

No. 2,074,098, "Rocket Airship"; Herbert L. Adams, Washington, D. C.

No. 2,114,214, "Self-Propelling Projectile"; Louis Damblanc, Paris, France.

No. 2,145,507, "Percussion Fuse for Rocket Projectiles"; P. E. J. Denoix, Paris, France.

No. 2,252,528, "Aircraft"; Igor I. Sikorsky et al, Trumbull, Conn.

No. 2,301,417, "Rotative Winged Aircraft"; Agnew E. Larsen, Jenkintown, Pa.

No. 2,319,149, "Jet Propulsion Engine"; George R. Micuta, Seattle, Wash.

No. 2,325,630, "Glider Launching Device"; James N. Petty, Maricopa County, Arizona.

No. 2,330,056, "Rotating Wing Aircraft"; Frank A. Howard, Elizabeth, N. J.

No. 2,332,670, "Aerial Bomb"; Wallace F. Rouse, Havelock, Iowa.

No. 2,356,557, "Reaction Propelling Device with Supercharged Engine"; Rene Anxionnaz, Paris, and Roger Imbert, Mantes, France.

No. 2,356,746, "Jet Propulsion Device"; Homer A. Boushey, Hamilton Field, California.

No. 2,364,676, "Skimming and Flying Vehicle"; Douglas K. Warner, Sarasota, Fla.

No. 2,364,677, "Compression Airplane"; Douglas K. Warner, Sarasota, Fla.

No. 2,372,250, "Combined Engine Cooling and Jet Propulsion Means"; Vincent J. Burnelli, Matawan, N. J.

No. 2,376,834, "Aircraft"; Norman A. Thompson, London, England.

No. 2,383,385, "Jet Propulsion Power Plant"; Carl P. Heintze, Amityville, N. Y.