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PRACTICAL MECHANICS

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Rocket Propulsion

Further Notes on Its History and Development

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(*Continued from page 411, September issue*)

SHORTLY after the Valier liquid fuel car trials of April, 1930, the original vehicle was adapted to greater power by the provision of an improved Heylandt rocket motor. Trials of the car using the new reaction system were scheduled for May 17th.

It was while carrying out a final check of the fuel tank capacity, just prior to the initial test, however, that an accident occurred—Max Valier being instantly killed when an explosion completely wrecked the vehicle. Thus, at the age of 35, a brilliant career was brought to a most untimely end. In memorial of this great rocket engineer, David Lasser (founder of the American Interplanetary Society) dedicated his book, *The Conquest of Space*, published in 1931: "To Max Valier, the first to give his Life for the Conquest of Space."

Coupled with the success of Dr. Goddard's early work in the field of liquid propellant research, the very promising results achieved in the Valier car trials, using the Heylandt constant volume combustion chamber, undoubtedly did much to promote widespread interest in the possibilities of liquid rocket fuels.

Solid Fuels and their Control

As has been mentioned earlier, the German rocket vehicle and aircraft experiments served to emphasise the point of limited control in the employment of the solid fuel, illustrating effectively that, once ignited, it is virtually impossible to regulate the reactive effort of any single powder charge. Opel and Valier, of course, had achieved a certain though small degree of control by the simple procedure of employing a *number* of ordinary powder charges, firing them in sequence; but, as will be readily appreciated, this solution was by no means adequate for truly practical purposes.

The firing duration of this system, too, had severe limitations. As an example, it is of interest to note that a single 10lb. charge of the rocket battery employed in the 'plane in which Fritz von Opel made his memorable flight of 1929 operated for a period of only 25 seconds while developing an average thrust of 53lb.

The solid propellant is generally contained *within* the "combustion chamber" (a tube closed at one end and constricted to form a narrow orifice at the other), and upon ignition the fuel burns rapidly without exploding, the gases developed exerting considerable pressure inside the chamber before their final ejection in the form of a high-velocity efflux.

A German design evolved in 1930, developed on the lines of the liquid propellant constant volume combustion system, provided a pressure feeding arrangement in which it was intended to actually *pump* powder fuel into a combustion chamber from a separate containing tank. However, the device when tested proved unreliable in operation, mainly because of the high-feed system pressure, which invariably caused premature explosions while the fuel was being forced into the combustion chamber.

It was Dr. Goddard, however, who provided the most satisfactory solution to the problem of solid propellant control in a reloading mechanism which has since become known as the "cartridge injector." This device consisted essentially of a combustion unit, which recoiled under the action of thrust, and by means of its travel successive charges of nitro-cellulose powder were automatically fed, reloading being effected in much the same way as in a rapid-fire gun. Much of the early work concerned with the "cartridge injector" was carried out in 1918—at about the same time as Dr. Goddard's early powder researches, mention of which has already been made. Later, however, the device was improved to enable a greater number of cartridges to be fired than had hitherto been possible. This particular motor formed the basis of a design for an unmanned rocket projectile intended to penetrate to outer space and reach the moon. Its arrival on the lunar surface was to have been marked by the firing, on impact, of a flash powder charge, the rocket being directed to fall on that portion of the moon in shadow. It was considered that the combustion of merely a few pounds of flash powder would be sufficient for astronomers on earth to recognise the projectile's arrival. Dr Goddard's figures give the total initial mass for such a projectile as eight to ten tons.

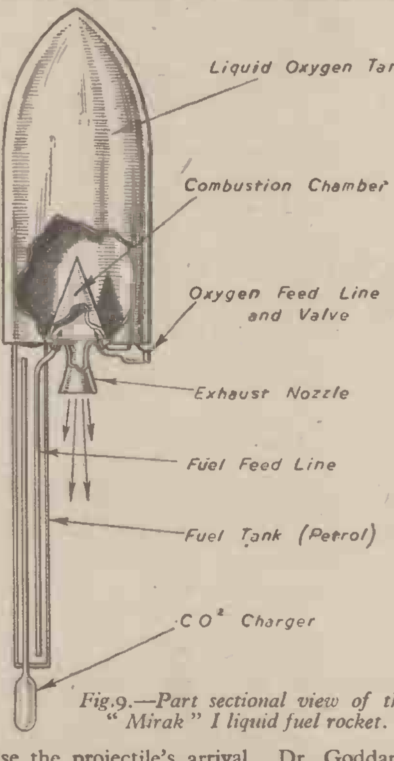

Fig.9.—Part sectional view of the "Mirak" I liquid fuel rocket.

Tiling Powder Rocket

Mention has already been made of the highly successful Schmiedle postal rockets, which employed powder as fuel; but this experimenter was by no means alone in his adherence to the solid propellant. Ing. Reinhold Tiling, for instance, carried out several highly successful powder rocket experiments during the early 1930's, and many of his rockets proved well able to rise to heights of over a mile, attaining speeds in excess of 700 m.p.h. A rather interesting feature of the Tiling projectile was that instead of providing a parachute for landing, a retractable rotor blade device was fitted, operated by means of a clockwork timer, the rocket wafting down to earth emulating the autogyro. Other Tiling projects included winged projectiles, and although not of a very great size—one particular type being 4ft. 6in. in length and nearly 7ft. span—their performances were highly creditable. Many of Tilings rockets were mail-carriers, and one of his most successful postal "shots" took place in 1931, when a projectile containing 200 items of mail was "shot" for a distance of nearly 6,000ft. Two years later, in October, 1933, while engaged on research concerning some 40lb. of powder, Ing. Reinhold Tiling, and three assistants, were killed as the result of a sudden explosion which destroyed the small building in which they were working. This tragedy provided dramatic proof of the severe instability of pre-mixed fuel, and undoubtedly did much to hasten the decline in interest amongst rocket authorities of the solid propellant. Nevertheless, Tiling was by no means the last to employ fuel powders, as it is intended to show in a subsequent article.

The Oberth Step-rocket

Meanwhile, Professor Oberth was busy developing a theoretical basis for flight in interplanetary space, his investigations being based on the *step-rocket* principle.

The space-vessel proposed by Oberth consisted of three *steps* (independent rocket units, each containing their own fuel and motors), the calculations being based on the most powerful fuel available—liquid oxygen/liquid hydrogen.

The weight disposition was calculated as follows: For the first *step* (at the head of the vessel) he proposed a total weight of 80 tons; 60 tons fuel, 10 tons structure and 10 tons payload (crew and equipment), this being the smallest of the *step* units. The second *step*, attached beneath the first, would include 480 tons of fuel and 80 tons structure, bringing the combined weight of the two to 640 tons. To this a third and final *step* was added, consisting of 3,840 tons of fuel and 640 tons structure, makiug the total initial mass weight for the complete vessel 5,120 tons.

It must be borne in mind that the initial mass of 5,120 tons would be sufficient only to gain release velocity from the earth's gravitational influence, and would not provide for return. To enable the vessel to return to earth a fourth *step* would be required, and, working to the same ratio, this would bring the total weight of the initial mass to 40,960 tons—clearly, not a truly practical solution.

Oberth conceived the operational sequence as follows: The third *step* would be employed first, the 3,840 tons of fuel contained being sufficient to impart to the complete vessel a velocity of 2½ miles per second. As soon as the fuel in this step had been consumed the empty structure would provide only dead weight to the vessel, and would therefore be detached and either destroyed by explosives or returned gently to earth by parachute in order to minimise risk to life and property.

The vessel, now consisting of two steps, is travelling at a velocity of 2½ miles per second, and weighs merely 640 tons. The second *step* would next be operated, the 380 tons of fuel contained permitting a further rise in speed of 2½ miles per second. Once more, when the fuel in this *step* is exhausted, the dead weight would be jettisoned, leaving the first and final 80 ton step with a momentum of 5 miles per second. Of this, 60 tons is fuel—sufficient to increase the velocity to 7 miles per second, and so obtain gravitational release.

From the above it can readily be appreciated that the key to economic space flight is in the jettisoning of irrelevant material as the vessel proceeds against a constantly diminishing gravitational influence. The vessel is made progressively lighter, and in consequence a considerable economy in fuel is effected. Thus an interplanetary vessel not designed on the *step* principle would be of even greater initial mass than the Oberth conception.

It should not be concluded from the above that an interplanetary space-vessel must necessarily be of such proportions as in the case given. Nor does the solution remain alone in the discovery of some as yet unknown fuel of high energy characteristic. The answer is involved in many considerations, chief amongst which are—(a) the development of rocket combustion motors of high thermo-mechanical efficiency, and (b) provision of the highest possible fuel/weight ratio.

Film "Girl in the Moon"

On behalf of the Verein für Raumschiffsfahrt E.V., Professor Oberth gave technical assistance in the production of the German Ufa film "Frau im Mond" (Girl in the Moon) adapted from the novel by the well-known German authoress, Thea von Harbon. For filming purposes a sizeable model space-ship was built, and in recognition of Oberth's part in the production, and also to gain publicity for the film, the Ufa group sponsored the building of a large liquid fuel altitude rocket. Unfortunately, for financial and other reasons, construction was never finally completed. Nevertheless, the film when finished in the early 1930's was a complete success, and undoubtedly did much in the way of publicity for the German society.

The "Mirak" Programme

The constant volume combustion chamber employing liquid fuel had shown great promise in the early tests of the type conducted by Goddard, Heyland and Valier, and this success undoubtedly influenced the Verein für Raumschiffsfahrt engineers in their decision to conduct a detailed series of experiments to determine the most efficient combustion chamber forms, and the most satisfactory methods of liquid propellant feed.

The first series of experiments (known as the "Mirak" programme) covered the development of a number of small rocket units, these being originated with the view of obtaining empirical data upon which to base the design of further rocket motors on a more exacting basis. The "Mirak" (lesser rocket) rockets were not designed with the intention of their being fired in free flight, but rather for rest on a special proving stand, a device with which it is possible to record such essential data as the thrust reaction and the exhaust velocity, the former being registered direct by means of a sprung attachment, the latter being computed from the thrust and amount of fuel consumed. This particular proving stand served a dual purpose in that, should the rocket units satisfactorily conclude their ground trials, by means of a launching attachment they could be actually shot in free flight.

"Mirak" I : Design

Work on the first liquid fuel rocket of the experimental programme, "Mirak" 1 (Fig. 9), was commenced early in 1930, a main feature being that a gas (pressure) system was provided for feeding the propellant.

The design incorporated a tankage space in the form of a stream-lined nosing shell, wherein the liquid oxygen was contained, a combustion chamber of conical form being situated within, its efflux nozzle protruding centrally from the tank base. Off-centre to the nozzle a single tube containing fuel petrol was situated, at the extreme end of which was fitted a small CO^2 pressure charger for feeding the fuel. Valves incorporated in the feed lines connecting the respective tanks to the combustion chamber were provided for controlling the rate of delivery.

As has already been mentioned, liquid oxygen evaporates rapidly at normal atmospheric temperatures, and good account of this peculiarity was taken in the design, it being found that the self-developed pressure would be amply sufficient to force the oxygen to the combustion chamber without additional aid. Heat from the combustion chamber served to increase the rate of evaporation, the liquid oxygen acting in reverse as a coolant for the motor.

Materials

Particular attention was required in the choice of materials. It was found, for instance, that many metals were apt to become brittle in contact with liquid oxygen, and this factor naturally set a problem in the construction of the tank. At the other end of the scale the construction of the combustion chamber, too, demanded careful attention. A material was required capable of resisting the intense heat likely to be generated, and one also that would not disrupt under high pressure.

After due consideration, it was decided to employ, in this first design, duralumin for both the oxygen and fuel tanks, and a special heavy copper alloy for the combustion chamber.

Trials

The first "Mirak" was completed well before the end of the year, and, although tests proved it a satisfactory first step, several preconceived design notions were severely shattered.

The most obvious fault was found to be in the shape of the combustion chamber, which, due to its form, severely restricted the exhaust flow. Efficiency suffered from incomplete combustion, and, in the light of initial trials, it became apparent that the combustion chamber lacked space at the top for the gases to mix adequately prior to their ejection from the nozzle.

After a series of exhaustive tests, "Mirak" 1 exploded. An examination of the remains showed that the explosion had been caused by the too vigorous expansion of the liquid oxygen, resulting in the development of excess pressure, which had burst the oxygen tank. It was obvious that heat transmitted from the combustion chamber had been the direct cause.

The Raketenflugplatz

While trials of the first "Mirak" were proceeding, officials of the Verein für Raumschiffsfahrt E.V. were engaged in the searching out of a suitable site for the establishment of a permanent rocket research station, where possibly dangerous experimentation could be carried out at a safe distance from habitation.

In the autumn of 1930 a stretch of land ideal for both ground and free-flight tests was finally secured at Reinickendorf, a suburb of Berlin; and there in September of that year the society established their experimental headquarters under the name Raketenflugplatz (rocket-flying field), where later buildings were erected and the rockets actually constructed.

(*To be continued*)

ITEMS OF INTEREST

20,000 Atlantic Crossings

THE twenty-thousandth transatlantic air crossing since the war began was recently made when an aircraft landed at an R.A.F. Transport Command airfield in Scotland. The flight was accomplished by an aircraft of British Overseas Airways Corporation North Atlantic return ferry, operated by B.O.A.C. to the requirements of Transport Command.

Most of these crossings have been from east to west over the Atlantic, and have been made by British, Dominion, American and Allied aircrews. The twenty-thousandth crossing emphasises the enormous increase in freight and passenger air traffic, as well as in the delivery of new aircraft, between America and the United Kingdom.

From the autumn of 1940 until Christmas Eve, 1943, the Atlantic had been flown 10,000 times. By the middle of May, 1944, the figure was 15,000, and now, less than three months later, another 5,000 flights have been achieved.

The majority of the aircraft delivered to the United Kingdom has been produced in the United States and the balance in Canada. Behind the achievement of the twenty-thousandth crossing is a story of organisation and high endeavour.

Vehicles and tanks coming ashore from a landing craft during the embarkation of British troops in Italy.