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NAVAL BOMBARDMENT

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PRACTICAL MECHANICS

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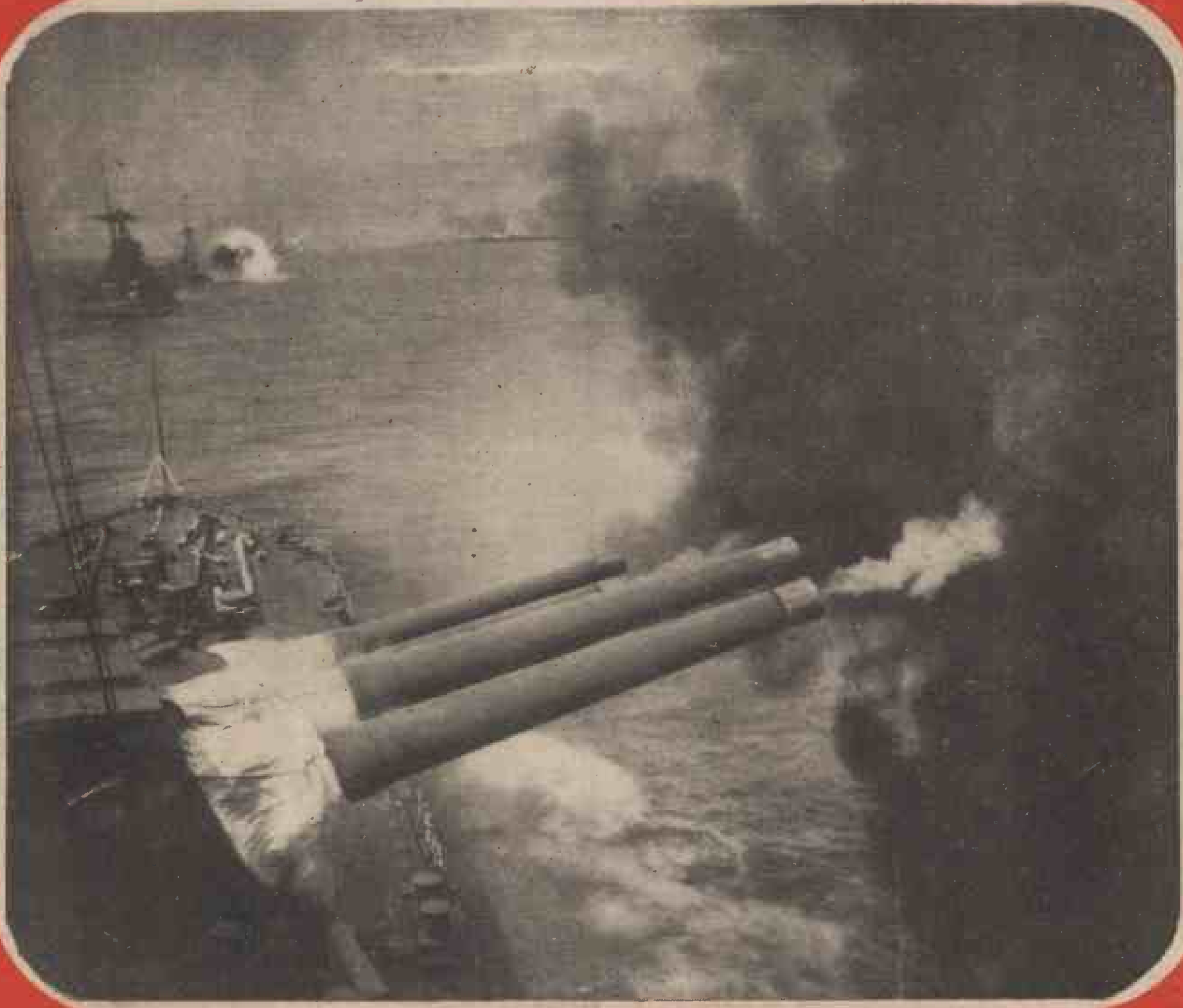


Rocket Propulsion

Its History and Development

By K. W. GATLAND

(*Continued from page 375, August issue*)

THE war of 1914-18 found the signal and illumination rocket (the latter ejected a parachute flare at the peak of trajectory) used extensively on the fighting fronts, and towards the end of the conflict a special message-carrying rocket projectile was developed, which found its greatest use for maintaining communication between advanced troop elements.

Rockets projected from aircraft were also employed during the war for destroying observation balloons and airships. The projectile, which was of the conventional "stick" balanced type, consisted of a simple tubular case containing gunpowder propellant compound, and incorporated at the "head" a number of barbs which enabled the missile to cling to the fabric of the target, the rocket exhaust being sufficient to fire the highly inflammable hydrogen gas contained.

The first operational aircraft to employ rocket projectiles as offensive armament appeared in 1915. This machine, a Henry Farman, carried ten rockets, these being electrically fired from small tubes situated on the outermost interplane struts, five either side. Several Newport Scouts were later fitted to carry eight rocket missiles mounted and fired in similar manner.

In 1917, the Vickers aircraft group developed a special single-seat, pusher type, rocket-firing aircraft (the Vickers F.B.25), designed as a defence machine intended to counter Zeppelin attack. However, this 'plane did not realise operational service, due to the introduction of incendiary ammunition for use in the ordinary aircraft machine-gun.

An interesting suggestion aimed at the increase of the flight efficiency of shells, particularly rocket shells, was put forward by Chilowsky in 1915. In order to reduce drag at high speed, he advocated the projection of a flame ahead of the projectile in order to raise the temperature of the air locally at the nose, the heated air thereby becoming less dense. For instance, it has been estimated that by means of the combustion of 10 gm. of phosphorus, it is possible to halve the resistance of the standard 75 mm. F.N. projectile.

The "Thrust Augmenter"

A French engineer, Henri F. Mélot, whose work, although being concerned solely with the development of thermal-jet power units, produced in 1917 an interesting design (Fig. 8) incorporating a multi-nozzle device of progressively increasing dimensions emulating from around the nozzle of a combustion chamber, the motor employing inducted air, with petrol as fuel. This "stage" nozzle served to induct air to augment the thrust of the propulsive jet, and was tested under the auspices of the French military authorities during the latter stages of the last war, though with no definite success. The principle upon which the device functioned was that air was sucked into the unit by virtue of an area of negative pressure created by the exhaust flow from the producing plant being expanded through a venturi "diffuser" tube, which thereby increased the mass flow of the efflux. Since the war, the "thrust-augmenter," as the device was later termed, was further developed by Mélot and others. In 1927 the Mélot "augmenter" system was tested at the Langley Memorial Aeronautical Laboratory, U.S.A., the results of which proved conclusively the efficiency of the device. It is quite probable that, by careful design, the "thrust-augmenter" may in later development provide the means for operating the "true-rocket" system in atmosphere at a practical efficiency.

Further Goddard Research

Mention of Dr. Robert H. Goddard's early researches has already been made, and in 1919 the findings of these initial investigations and experiments were published in the form of a report to the Smithsonian Institute—"A Method of Reaching Extreme Altitudes" (Smithsonian Miscellaneous Collections, Vol. 71, No. 2). Investigations at the Clarke University were maintained during 1919 and for some years following, the immediate aim being the establishment of a firm foundation from which it would be possible to base the design of a practical sounding rocket, capable of penetrating to heights prohibitive to the balloon and the aeroplane, for the purpose of providing much-needed data of atmospheric conditions at extreme altitudes.

Dr. Goddard is reputed to have conducted preliminary research concerning liquid fuels (which are capable of being throttled to

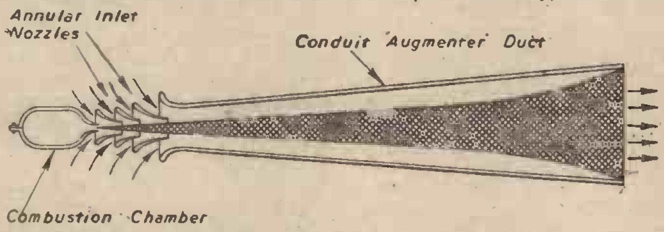


Fig. 8.—Mélot type thrust augmenter. Air is sucked in at the sides by virtue of negative pressure created within the conduit duct by the fast-moving exhaust efflux.

the combustion chamber under direct control, thereby maintaining a constant chamber volume throughout the entire firing period), in 1922, when he first put forward the suggestion of employing petrol as fuel, burnt in a medium of oxygen, this latter element being contained in concentrated *liquid* form. It should not, however, be concluded that liquid propellant owes its origin to Goddard alone, for Professor Oberth, as early as 1914, is held to have proposed liquid oxygen and liquid hydrogen as a plausible rocket fuel.

The process concerned in the reduction of a gaseous element, such as oxygen, to the liquid involves the gas first being highly compressed. Once a sufficient pressure has been attained, the gas is suddenly allowed to expand, thereby reducing the temperature, and by means of a series of such processes the gas finally assumes liquid form, in the case of oxygen at 182.9° C. Special vacuum containers, of the Dewar or "thermos" type, are required for storage as vaporation quickly takes effect, acting to return the liquid to its original form at normal atmospheric temperatures.

Two more pioneers of modern rocket development were an Austrian, Dr. Hermann Oberth, and Dr. Walter Hohmann, of Germany, whose early theoretical researches, unlike Goddard's, dealt almost entirely with the rocket in space. After extensive investigation, a treatise was finally developed in 1923 in which Oberth set out a technical observation of the rocket as a means for interplanetary communication. This work was later published as a book entitled "Die Rakete zu den Planetenräumen" (92 pp.).

Reverting once more to the French rocket pioneer, Esnault-Pelterie, a lecture was delivered by him to the main assembly of the French Astronomical Society on June 8, 1927, the subject-matter concerning both the aspect of altitude sounding by rocket, leading to the possibilities of the interplanetary space-vessel. A year later the lecture was published as a book entitled "L'Exploration par Fusées de la Très Haute Atmosphère et la Possibilité des Voyages Interplanétaires," and in 1930 this work, considerably expanded to include in addition to its original matter an extensive mathematical investigation covering rocket performance and trajectories, was published under the title of "L'Astronautique" (249 pp.). The work remains to this day the greatest theoretical treatise of rocket propulsion yet produced.

In June, 1927, the world's first successfully organised rocket research group, the "Verein für Raumschiffahrt, E.V." (Society for Space Navigation), was formed in Breslau, Germany, due mainly to the endeavours of Max Valier and Ing. Johanes Winkler, and it was not long after inauguration that the society listed amongst its members such renowned names as Professor Oberts, Dr. Hohmann and Willy Ley.

Rocket-car Trials

The society commenced active experimentation a year after its formation, the first series of tests concerning the propulsion of road vehicles, and although the experiments concerned can hardly be said to have contributed greatly toward the technical advancement of rocket propulsion, considerable public interest was nevertheless aroused.

This early work was sponsored by a notable German car manufacturer, Fritz von Opel, probably with the view in mind that the sensational nature of the experiments would serve as a good advertisement for his more conventional products. At all events, the first rocket car to be developed by the society was tested on March 12, 1928, at the Ruessilsheim racing circuit, and a month later a similar test took place as a public demonstration. The car itself, designed by Max Valier, was of light construction, and powered by twenty-four individual gunpowder charges, each weighing twenty-six pounds. These charges, specially manufactured for the test by Ing. F. W. Sander, were arranged in "block" form behind the single driving seat, firing taking place in sequence. Ignition was either accomplished electrically or by means of a clockwork timing device.

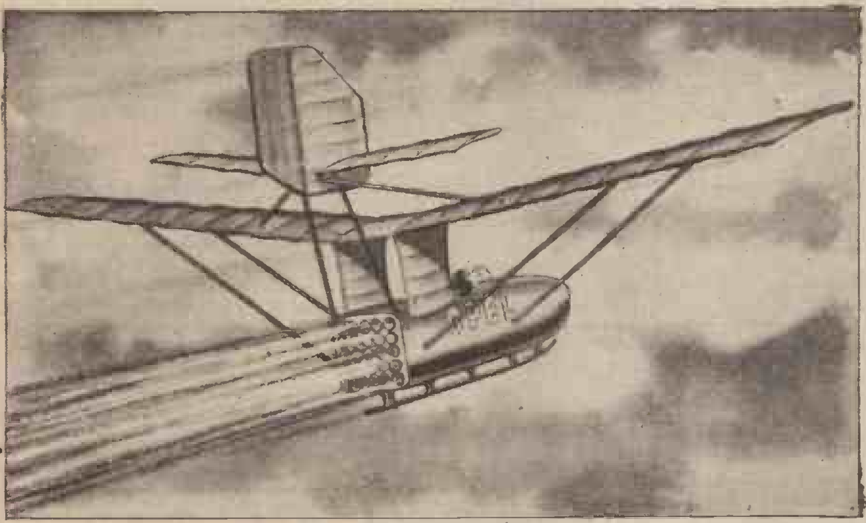
Von Opel's Experiments

On May 23, 1928, with von Opel himself at the wheel, a further public demonstration took place, on this occasion at the Avus

Speedway, Berlin. From a standing start, the car is recorded to have accelerated to a velocity of 60 m.p.h. in five seconds, attaining a maximum speed of 131 m.p.h.

So pleased was von Opel by the success of the Avus Speedway trial that he sponsored three more rocket cars, these being constructed before August of the same year. Unfortunately, due to an accidental explosion, the fourth car was seriously damaged shortly after its completion, but the remaining two satisfactorily completed their respective trials, although the results obtained did not in any way compare with those achieved on May 23. Further types were run on rails, and in one particular instance a speed of 62.5 m.p.h. was attained within 5 seconds from a standing start.

A particularly interesting point was that "retaining planes," emulating stub wings, were fitted to a later Opel rocket car. These projected outwards from a point behind the front wheels, and were set at a negative incidence, the object being that, as the car gained speed, air pressure would act upon the planes and so restrict any lifting tendency.



The Opel rocket-propelled aircraft (1929).

The First Rocket Aircraft

On June 11, 1928, the first man-carrying rocket aircraft flight was made, the machine employed being a light tail-first type Rhön-Rossittengesellschaft glider, powered by two large powder charges, and piloted by Friedrich Stahmer. The flight in question was commenced from a point in the Rhön mountains, the 'plane travelling for nearly a mile before descending. Later a further and much sturdier machine of tailless form was constructed which incorporated four propellant tubes.

Rocket Mails

In July of the same year an Austrian engineer, Ing. F. Schmiedle, conducted experiments aimed at the development of a rocket mail-carrier. Six experimental rockets were constructed, and subsequently tested in free flight, delicate registering instruments being housed within special nose compartments. Unfortunately, the sixth rocket exploded, destroying every item of its valuable load.

As the direct result of these preliminary experiments, Schmiedle established in 1931 the first officially recognised rocket mail service, projecting his mail-carriers for a distance of two miles over mountainous country connecting the two Austrian towns of Schöckel and Radegund with a high degree of accuracy. In fact, so confident were the authorities in this rocket postal service that even registered letters were entrusted to the Schmiedle service for delivery.

A parachute enabled the projectile, which contained the mail in a nose compartment, to reach the ground without damage, being automatically released as the rocket ceased firing.

Further German Experiments

On July 18, 1928, Max Valier himself tested a specially built all-wooden car of his own design, attaining a speed of 112 m.p.h., using gunpowder as propellant. Two further tests were made later, and during the latter he achieved a velocity of just over 130 m.p.h. before disaster overtook him, the car overturning at speed and ending as a complete wreck. Happily, no serious injury was sustained.

Undaunted by the car mishap, Max Valier continued his experiments, and on February 3, 1929, conducted trials of a rocket-propelled sleigh on the ice-covered Lake Starnberg, Germany. In this test a maximum velocity of 235 m.p.h. was attained, and Valier, highly pleased with the success of this latest venture, next resolved to take the air in a rocket 'plane. His plans involved the actual design of a special machine capable of spanning the Channel, which he hoped to fly, from Calais to Dover, but for a variety of reasons the project was never developed into reality.

On September 30, 1929, Fritz von Opel himself piloted a rocket glider, specially designed by Ernest Hatry, powered by some twenty Sander gunpowder charges. In this craft von Opel attained a maximum speed of 85 m.p.h., the machine flying for a distance of one and a half miles at a more or less constant altitude of 50 feet. Unfortunately the 'plane was rather severely damaged on landing, but fortunately the pilot escaped without serious injury.

However, although widespread interest was attracted by these full-scale tests of powder-driven rocket vehicles and aircraft, the Verein für Raumschiffahrt E.V. engineers soon began to realise that nothing of real technical value was being gained. Nevertheless, it had to be admitted that the experiments did act to emphasise one very important point, namely, that the degree of control attainable using powder fuel was practically negligible, as once the propellant charge was fired the reactive thrust of any one charge could not be increased or diminished at will. Thus it is probable that these experiments considerably hastened the inevitable introduction of *controllable* liquid fuels; but we must turn to America for the first practical demonstration of this unique fuel form.

Fuel Liquids

Dr. R. H. Goddard is credited with the initial application of fuel liquids, the particular experiment concerning the firing of a rocket projectile nine feet in length and twenty-eight inches in diameter, employing liquid oxygen, with petrol as propellant. The projectile, which contained special light meteorological instruments, was fired from a 40-foot high steel tower, the test being carried out on the outskirts of Worcester, Mass., on July 17, 1929. Although the projectile exploded after reaching an altitude of nearly 900 feet, the test was considered to have been highly successful, so much so that Goddard received a donation equivalent to the sum of £20,000 from the late Daniel Guggenheim for the continuance of liquid propellant research, although only after extensive investigation of his claims.

After assisting in the preparation of another technical rocket work, "Die Möglichkeit der Weltraumfahrt; Allgemeinverstandliche Beiträge zum Raumschiffartsproblem" (344 pp.), Professor Oberth greatly expanded his first treatise, "Die Rakete zu den Planetenräumen," and in 1929 a new 431-page edition was published.

Also, in 1929, the REP-Hirsch award, a fund originated by Esnault-Pelterie and a wealthy banker, André Hirsch, was established, which aimed to encourage the development of the newly born science of *astronautics* (space-flight) by the annual award of a sum of 10,000 francs, to either the author of a most original technical literature or in recognition of an especially significant experimental work. A committee, comprising many eminent scientists of the French Astronomical Society, was formed to assist in the selection, and in its initial sitting of June, 1929, this body was unanimous in recording the first award to Professor Hermann Oberth.

Research in the U.S.S.R.

In Russia, as indeed in many other countries, the developments of European and American rocket research workers were being followed with ever-increasing interest, and finally, in 1929, two U.S.S.R. rocket research groups were formed—one the Moscow G.I.R.D., founded by Ing. I. Petrovitch, and the other the Leningrad G.I.R.D., founded by Professor N. Rynin and Dr. Jakow I. Perlmann. Professor Rynin later contributed a comprehensive work entitled "Interplanetary Traffic" (9 vols.), which did much to promote Russion interest in the possibilities of space-flight. The Russian engineer, K. E. Ziolowsky, too, had not been idle since his preliminary work of 1903, and many more original papers by him were published concerning both the application of the rocket principle for rapid terrestrial transport, and also as a means for achieving interplanetary communication.

Liquid Fuel Rocket Car

It is of interest to recall yet another German rocket car development, this time the propellant employed being liquid oxygen, with denatured methylated spirit as fuel, in accordance with Professor Oberth's investigations. The reaction motor, into which the propellant mediums were pressure fed, was designed by Dr. Paul Heylandt and scaled barely seven pounds. Tests proved it capable of developing a maximum of 50 h.p. In April, 1930, an initial trial was held at the Tempelhof Aerodrome, Berlin, in which the car accelerated to a maximum speed of 60 m.p.h., and although the velocity attained was not half that reached by the earlier powder fuel vehicles, in consideration of the fact that the constant volume combustion chamber was then in its most embryonic stage, the test was concluded to have been highly successful.

is not as expansible as the brass. Thus the free end of the rim tends to be drawn into the centre of the wheel as the brass portion tends to expand the rim outwards. Such a contraction, by making the diameter of the wheel smaller, tends to quicken its rate of oscillation and thus to increase the rate of the clock. These two opposing effects cancel each other out very satisfactorily and so produce virtually a wheel which has one constant rate of oscillation within any reasonable temperature-range.

At lower temperatures the opposite to the above effects take place, the brass outer rim tending to contract and the free end of the rim tending to be drawn outwards. Here, again, however, the wheel still retains very satisfactorily a constant rate of oscillation.

Earnshaw put various adjusting screws into the rim of his balance-wheel and thereby brought into existence a valuable form of compensatory construction which, with one or two modifications, has persisted to the present day.

The Transit Clock

A lesser-known triumph of Earnshaw's was his improvement and simplification of the great "transit" clock at Greenwich Observatory. This mechanism had originally been made by George Graham, another inventive clockmaking genius, at a much earlier date, but it had become cumbrous and not a little old-fashioned, so much so that it called for the hands and brain of a later horological genius to launch it again on a new and a very much extended lease of practical life.

The chronometer is, perhaps, the most perfect piece of mechanism which has ever been devised. Nowadays, marine chronometers can by various compensating devices be adjusted to a working accuracy of 1 in 500,000.

It is curious, perhaps, that the present age, which witnesses this truly astonishing triumph of horological precision, should also see the chronometer as an everyday timekeeping instrument decreasing in importance. Yet such is a fact, for nowadays a ship need not necessarily carry a chronometer provided that it possesses a reliable radio installation, by which latter means it can obtain the necessary time signals from any land installation.

Nevertheless, seagoing vessels carry at least two portable and independently adjusted chronometers of great accuracy which are maintained as standbys in case of any failure on the part of the radio, and, in general, it would seem that this efficient instrument will long remain in marine use in view of the complete independence of land-station communication which it confers upon a seagoing vessel.

Reaction Motor Propellant Feed

A Summary of the Problems Entailed in the Feeding of Propellant, in "True-rocket" Aircraft Systems.

By K. W. GATLAND

THE problems relating to the feeding of propellant to the reaction chamber, especially in connection with the volatile "supporting" element, liquid oxygen, are numerous and complex, and feed systems, apart from being dependable in action and simple to service, must provide injection of large quantities of fuel, in correctly metered proportion, at high pressure, and within wide temperature extremes.

Liquid Injector Methods

The use of liquid oxygen, or any of the gaseous elements reduced to the liquid, present such difficulties as the freezing of the priming lines, backfiring and overheating, as the result of incorrectly metered fuel delivery, and the problems of vapour lock (due to the reducing atmospheric pressure with altitude, in rapid ascent), owing to an increased rate of vaporation of the fuel.

There are two general forms of liquid feed, the *pressure* type, in which the fuel is force fed by the action of an inert gas, such as nitrogen or carbon dioxide, while the other feed method functions with the fuel tanks at atmospheric pressure, employing some form of *mechanical pump*.

The simplest form is the *pressure* feed type, where the "supporter" (i.e., liquid oxygen) is expanded into the reaction chamber by its own pressure, the petrol, or other suitable fuel, being force fed by a gas charger. Despite the simplicity of this system, however, due to the different pressures within each tank, severe disproportion of the fuel impulse may quickly arise, and in the case of liquid oxygen, the tank may be subjected to wide pressure extremes, due to the boiling of the liquid. This is more noticeable when the pressure difference between the tank and the reaction chamber is small, since it is this difference which determines the rate of fuel delivery. Should an increase of oxygen develop against constant flow of fuel, oxidation of the reaction chamber, in which the oxygen clings to the wall surface, consuming the material as fuel, will often result in motor burn-out, with combustion temperatures as high as 3,000 degrees Centigrade. The method employed to ensure constant delivery is to use a nitrogen (or CO^2) charger tank, and introduce the high-pressure gas through check valves in both oxygen and petrol tanks.

One of the main drawbacks to the use of *pressure* feeds is the weight of the tanks due to their having to withstand the full reaction chamber pressure. Difficulties in handling and charging up, due to the high pressures, and the possibilities of leakages in the tanks, valves and in feed line connections, are also problems of some significance.

In view of these considerations, the *mechanical pump*, although, of course adding

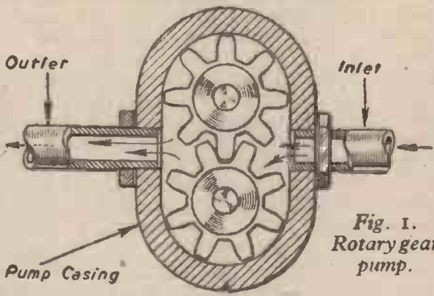


Fig. 1. Rotary gear pump.

complication, would appear to offer some solution, the main advantage being safety, with constant and high-delivery pressures. Perhaps the most effective type is the gear-pump (see Fig. 1), which consists of two meshed gears, revolving in a casing, operated by auxiliary drive. This pump adequately fulfils the requirements of a steady, continuously acting unit, permitting high-pressure delivery at a controllable rate, the fuel entering the pump, being carried round between the gear teeth.

Auxiliary Drive

The exhaust-driven turbine would appear to offer the most promising type of prime mover for the operation of the mechanical pump. Petrol reciprocating engines would require supercharging at high altitude and would consume a proportion of the fuel-load. It is possible that engines employing compressed gases operated by combustion-chamber pressure may be used. Superheated steam units might find their place, either operating a reciprocating engine or multi-stage turbine. Such plants would be in the form of flash-steam units, with heating pipes encompassing the reaction chamber "throat."

Problems entailed in the starting of the exhaust turbine, and the compressed-air gas motor, would naturally arise, but it is considered that pressure chargers for initial priming would suffice.

The Centrifugal Fuel Injector

The centrifugal injector (similar in principle to the centrifugal pump), developed provisionally by the "Astronautical Development Society" and the "Manchester Astronautical Association," is an example of a self feed unit, and apart from initial priming of propellant, the unit is completely automatic in operation. The rotary portion of the injector (see Fig. 2) consists basically of a centrifugal feed unit around which are equally spaced a number (three or more) of reaction chambers axially offset. Operation is as follows: Fuel and oxygen are initially primed to the reaction chambers by means of auxiliary pressure chargers, contained in the conical fairing. Upon ignition, thrust developed acts to rotate the unit, pressurising the fuel tank, and automatically releasing the oxygen feed valve, permitting the fuel and oxygen to pass to the centrifugal feed unit, where delivery is made to the reaction chambers in correctly metered proportion and at constant and high pressure.

The diagram shows an installation intended for petrol as fuel, with oxygen, but the working principle remains similar when other forms of fuel liquids are considered.

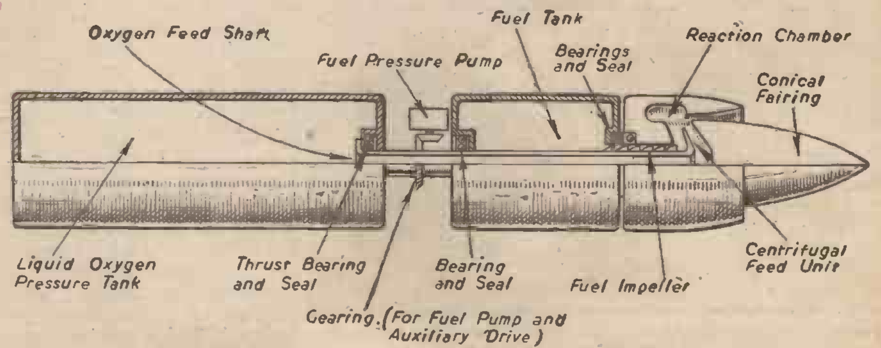


Fig. 2.—Sectional view giving details of the centrifugal fuel injector and oxygen and fuel tanks.