JOURNAL

OF THE

AMERICAN ROCKET SOCIETY

NUMBER 65 MARCH, 1946

Published by the

AMERICAN ROCKET SOCIETY INC.

A Critical Review Of German Long-Range Rocket Development

By W. G. A. PERRING

Introduction

Serious rocket development was started in Germany in the years 1929-1930 by a few groups of private inventors. This work attracted the attention of the Army Weapons Group in 1933, and in 1937-1938 a special research and development station was set up at Peenemunde at the cost of 300 million marks, and the work was transferred from Berlin to this new station at about that time.

Peenemunde concentrated mainly on bi-fuel rockets, employing liquid oxygen as the source of oxygen for the combustion of the fuel. Work was started on a range of rockets which they designated A1 to A10, only one of which, namely, A4 or as we know it V2, ever being used operationally.

Walter, working at Kiel, concentrated attention on H_2O_2, i.e., hydrogen peroxide, called by the Germans T Stoff, and with this fuel in combination with a suitable catalyst, he developed forms of rocket which were used quite extensively by the Germans during the war.

Apart from these main rocket developments, there were many other developments going on all over Germany; in some of these solid fuels were used, and in others nitric acid was the oxygen carrier, and Diesel oil or alcohol the other fuel.

It would be impossible in the space of this lecture to touch on all these developments, indeed since they all contain the same essential features, it will be sufficient to describe only one of them in detail. I propose therefore to describe the V2 rocket, and discuss the various factors affecting its performance, and only touch briefly on the other lines of development that went on in Germany.

V2 Rocket

The V2 rocket was the product of Prof. V. von Braun and his collaborators; Braun incidentally recognized that the V2 is still in a very undeveloped state, he is well aware of its shortcomings, and compares the stage of development reached with, say, the stage of development reached by the aeroplane in the last war.

Early work leading up to the V2 began in 1933, when the A1 rocket was designed. This rocket weighed about 330 lb., it was 4.6 feet long and had a diameter of about 1.0 feet. It was followed in 1934 by work on A2, which in dimensions was similar to A1, and differed only as regards the method of control. The A2 rocket fitted with a motor developing a thrust of 660 lb. for 16 seconds, was successfully launched, and reached a height of 6500 feet. Developments on A3 started in 1938. A3 weighed 1650 lb., was 25 feet long, and about 2.5 ft. in diameter. This rocket was fitted with a motor developing a thrust of 3300 lbs. for 45 seconds, it contained an automatic control system which operated rudders in the gas stream, and when fired vertically, it reached a height of nearly 40,000 feet, while it had a range of about 11 miles when launched at an angle.

Work on A4 commenced about 1940. A4 was a scaled up version of A3; firings commenced in July, 1942, and the first successful launch was in October, 1942, when the fourth rocket to

---

Reprinted from a paper read before the Royal Aeronautical Society, London, November 1, 1945.

be launched flew a distance of 170 miles. Orders for the production of the A4 rocket in quantity were given at the end of 1942, and the first attacks against this country started in September 1944. Information was, however, in our hands well in advance of this date. Experimental rockets sometimes have a habit of departing from their proper course, and this happened in the case of an A4 rocket fired by the Germans in June of 1944. This particular rocket, as I think most of you now know, air burst over Sweden. In so doing, it yielded two tons of rather small fragments, but upon examination these revealed most of the design features and enabled us to establish the rocket size and performance.

The early experience with these experimental rockets is quite interesting, in that it illustrates the difficulties that have to be overcome in a development of this kind. The first rocket fired on 6th July, 1942, rose about three feet from the ground, and then exploded, destroying the testing station. The second rocket rose 16,000 feet into the air and then exploded, and the third one suffered a similar fate. The fourth, as I have just mentioned, flew satisfactorily, so also did the fifth, though this is uncertain because the point of impact was not spotted. Then followed a succession of failures, 13 rockets one after the other failed to fly, some broke in two, others exploded, and none of them reached their target. During the development which followed, well over a hundred rockets were fired, and although at the end of this period break ups were less frequent, failures still did occur to some 15-20 per cent. of the rockets fired.

General Description

The leading particulars of the A4 rocket are set out in the following table. The rocket has an overall length of 46 feet, a maximum body diameter of about 5 ft. 5 ins. and an initial all up weight of about 12.5 tons.

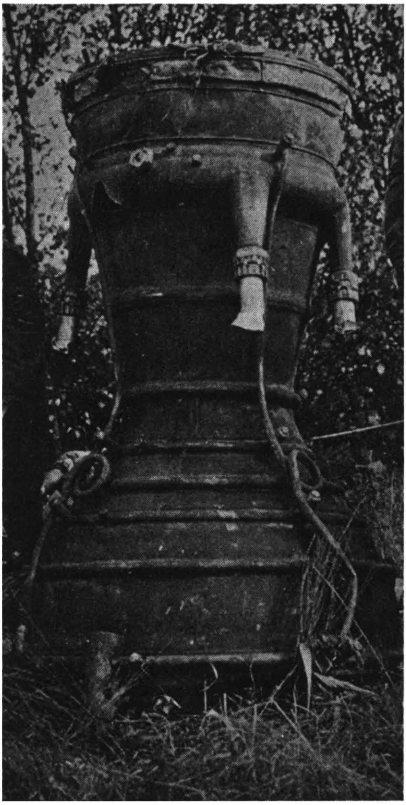
Table I

Leading Particulars of the A4 Rocket

Lengths	
Overall length of rocket	46 Ft.
Warhead	5 ft. 11 ins.
Instrument bay	4 ft. 8 ins.
Fuel compartment	20 ft. 3.5 ins.
Power bay (including Venturi)	14 ft. 7.5 ins.
Diameters	
Maximum diameter of body	5 ft. 5.3 ins.
Diameter over fins	11 ft. 8 ins.
Weights (for detail weight summary see Appendix I)	
Total loaded weight	12.5 tons
Warhead (with Amatol filling)	2,150 lb.
Structure	3,865 lb.
Power unit	2,235 lb.
Equipment	650 lb.
Main fuels (tanks full)	19,310 lb.
Auxiliary fuels	400 lb.

The warhead occupies the nose of the rocket, and housed immediately behind the warhead are the main control instruments and radio equipment. The outer shell of the rocket extending over this compartment is provided with large hinged panels, affording access to, and a ready means of servicing, the instruments carried. The main fuels are carried in two large light alloy tanks, occupying the central compartment of the rocket. There are two fuels, one a 75 per cent. solution of ethyl alcohol in water, occupying the forward tank nearest the nose, and the other fuel, liquid oxygen, occupies the rear tank.

The remaining space in the rocket is taken up by a turbine which drives the two main fuel pumps, and with the auxiliary fuel supply, then follows the main combustion chamber and exit venturi, and around this unit are the stabilizing fins, while projecting into the exit of the venturi are the main control vanes.



—British Official Photo.

Fig. 1. The jet unit of the German long-range V2 rocket.

Structure

The structure of the rocket is built up of steel ribs and stringers which are covered by thin steel sheeting. The sheeting is in general 0.025 inches thick but the stringers and formers vary, and their thicknesses range from 0.04 to 0.068 inches. The constructional features resembles closely normal aircraft practice.

The thrust of the jet is transmitted from the venturi unit, through a heavy tubular steel framework, to a circular angle frame at the forward end of the power compartment. This framework also forms the main supporting structure for the turbine and pump units.

The main fuel tanks are positioned by guides built into the outer skin covering, but the loads are taken directly by the circular angle frames, which form the ends of the fuel compartment. Provision is made to take up the very considerable differential expansion between the tank and outside shell cover that will occur during the filling process, and which will become even more accentuated during the rocket flight.

Forward of the tank compartment the structure changes, and over the space occupied by the control instruments and radio the rocket tapers, and the strength is provided by four main longitudinal members, which again terminate in a circular angle frame.

A conically shaped warhead, forms the nose of the rocket, and this is bolted to the circular frame at the end of the instrument bay. The warhead shell is of steel, about 0.25 inches thick, and it is not protected in any way from the conditions that will be experienced by the outer skin of the rocket during flight. The main circular angle frames, mentioned above, act as transport joints, thus enabling the rocket to be broken down into its various components, for ease of handling.

Propulsive Unit And Fuel System

The rocket is propelled by a jet of hot gases resulting from the combustion of two fuels, liquid oxygen and alcohol, the combustion taking place in a chamber which forms the front end of the venturi.

The fuels are pumped under pressure into this space by two turbine driven centrifugal pumps, the turbine being driven by a hydrogen peroxide-permanganate system.

Hydrogen peroxide contained in an elliptical steel pressure tank, and sodium permanganate contained in a small cylindrical tank are fed by means of compressed nitrogen to a burner. The

—British Official Photo.

Fig. 2 The forward end of the jet unit showing 18 jets and parts of the V2.

hot gases generated are then led along a lagged steel pipe to the ring main which feeds the turbine.

The turbine has one velocity compound impulse stage, with the rotor carrying two rows of blades. The turbine has partial admission to both rows of blades, the inlet nozzles to the first blades being arranged in four segments, each with four nozzles per segment.

Each nozzle is of the convergent-divergent type, and the ratio of the throat to outlet area, corresponds to a pressure ratio of about 20 to 1. The turbine drives two centrifugal pumps, and the performance of the turbine and pumps under operating conditions are set out in Appendix II. These figures are estimates, but they agree fairly closely with statements on performance that have been put forward by various German workers.

The pumps deliver about 275 lb. of fuel per second at about 350 lb. per in.^{2} pressure, and at this rate of discharge the main tanks would be exhausted in about 70 seconds.

Both main tanks are pressurised to about 1.4 atmospheres, partly to assist the pumps, and partly to prevent the tanks collapsing. Pressure in the alcohol tank during the initial stage is achieved by ram compression, a pipe from the tank being led forward through the warhead to an opening near the nose. After about 40 seconds, however, owing to the fall off in air density this method of pressurising is no longer effective; a valve in the pipe is then closed, and pressure is provided by supplying nitrogen from a group of bottles housed in the instrument bay.

On the oxygen tank a special vent valve is fitted that maintains the pressure in the tank at 1.2 atmospheres, but during the operational period this pressure is raised to 1.5 atmospheres, the pressure being kept up by supplying oxygen which is evaporated by a heat exchanger placed in the exhaust of the turbine system.

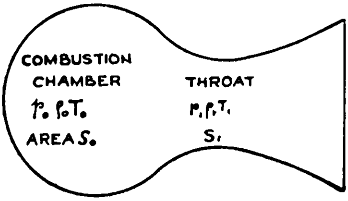
Fuel from the pumps is passed to distributing valves, the liquid oxygen being fed to eighteen brass roses, located at the base of open-ended cups formed on the end face of the combustion chamber, while the alcohol is pumped to an annular ring at the rear end of the venturi, where it enters a cooling jacket which surrounds the venturi. The venturi is a propulsive nozzle of the convergent-divergent type. It is of heavy welded mild steel construction, a large portion of it being jacketed, to accommodate the alcohol coolant. Most of the cooling is external, and the alcohol after passing between the double walls is finally led to the eighteen cups on the end face of the combustion chamber, where it discharges through a ring of small nozzles and mixes with the liquid oxygen.

A small amount of alcohol, however is fed into the venturi through rings of small holes drilled at several positions along its length, thus providing some degree of internal wall cooling. Although the gas temperatures in the combustion chamber and near the throat of the venturi reach 2700-2500°C., the cooling is very effective, since examination has shown that the skin temperatures on the inner surface has not exceeded 1000°C. The only trouble that seems to have arisen is a thermal expansion one, and small loops have been introduced into some of the feed systems to overcome this difficulty.

Rocket Motor Characteristics

Before going on to discuss the controls and control systems, it will perhaps be best to say something about the performance of the rocket motor and the way it was fired.

If we consider a simple system comprising a combustion chamber and venturi in which the fuels are burnt at constant pressure, and if we assume as the result of the combustion process, that the gases have a pressure, density and temperature given by po, Po and To, then by making use of the continuity relationship



—Crown Copyright

Fig. 3. Conditions in combustion chamber and venturi.

$$S\rho v = M$$

where S is the cross sectional area at any point, v is the velocity and M is the rate of discharge, and of the Bernoulli relation

$$v^2 = \frac{2\gamma}{\gamma-1}\frac{p_0}{\rho_0}\left(1-\frac{p}{p_0}\right)^{\frac{\gamma-1}{\gamma}}$$

together with the adiabatic law and gas laws which give

$$\frac{p}{p_0} = \left(\frac{\rho}{\rho_0}\right)^{\gamma} = \left(\frac{T}{T_0}\right)^{\frac{\gamma}{\gamma-1}}$$

it is possible to establish a relation between the shape of the venturi and its operating conditions, one form of which can be written

$$M = S\left(\frac{2}{\gamma-1}\right)^{\frac{1}{2}} a_0\rho_0\left[\left(\frac{p}{p_0}\right)^{\frac{2}{\gamma}} - \left(\frac{p}{p_0}\right)^{\frac{\gamma+1}{\gamma}}\right]^{\frac{1}{2}}$$

where y is the ratio of the specific heats and

$$a_0^2 = \gamma\frac{p_0}{\rho_0}$$

is the speed of sound in a gas corresponding to the pressure and density

In the case of the A4 rocket, the ratio of the discharge area to the throat area is 3.4 to 1, so that the square root of S_x/S_1 is 1.85 and consequently the ratio of the pressure in the combustion chamber to the pressure at exit must be about 20 to 1 if the venturi is to run full.

A photograph of the venturi of a Swedish rocket shows a venturi which is rather different to the production type: the main face of the combustion chamber being formed in light alloy and bolted to the remaining steel part of the chamber.

The conditions in the combustion chamber are of course dependent on the rate of delivery of the fuel, and on the characteristics of the fuel, and for the rocket to operate under ground level conditions with the gases discharging at atmospheric pressure, sufficient fuel must be burnt to maintain the pressure in the combustion chamber at 20 atmospheres, i.e., 294 lb. per in.², and the fuel pumps must be capable of maintaining the fuel flow at this pressure in addition to providing the pressure head necessary to overcome the losses in the fuel lines from the pumps and the losses through the nozzles. When the combustion chamber is subject to a pressure p_o, it is clear there is a net unbalanced reaction equal to $S_1 p_o$ propelling the rocket forward, since however the venturi converts some of the internal energy of the gases into useful work, the actual thrust will be greater than this value.

In discussing rocket fuels, it is often convenient to refer to their specific impulse (S_I), i.e., the thrust produced for every pound of fuel burnt per second. The thrust therefore can be written

$$T = M\,(S_I)$$

but the thrust can also be written

$$T = M\frac{v_x}{g}$$

where v_x is the discharge velocity, it follows therefore that

$$(S_I) = \frac{v_x}{g}$$

From the velocity relationship given earlier, we may write

$$v_x = \sqrt{\frac{2\gamma}{\gamma-1}\,\frac{p_o}{\rho_o}\left(1 - \frac{p_x}{p_o}\right)^{\frac{\gamma-1}{\gamma}}}$$

and this reduces to

$$v_x = \sqrt{\frac{2\gamma}{\gamma-1}\,\frac{p_o}{\rho_o}}$$

since the part in brackets tends to unity

Consequently the specific impulse of a fuel can be written

$$S_1 = \frac{1}{g}\sqrt{\frac{2\gamma}{\gamma-1}\,\frac{p_o}{\rho_o}}$$

or making use of the gas law

$$\frac{p}{\rho} = \frac{RT}{M}$$

where R is the gas constant, and M the molecular weight

$$S_I = \frac{1}{g}\sqrt{\frac{2\gamma}{\gamma-1}\,\frac{RT_o}{M}}$$

The specific impulse, therefore, varies as the square root of the absolute temperature of the gases in the combustion chamber, and inversely as the square root of the molecular weight. The pressure, however, in the combustion chamber varies roughly as the fifth power of the temperature, so that there are very severe practical limits to the gain that can result from higher working temperatures; but it is an advantage to work with gases having low molecular weight.

The fuel used in the A4 rocket has an (S_I) of about 220 under ground operating conditions; consequently the velocity of discharge of the gases is about 7000 ft. per sec., and since 275 lb. of fuel are burnt every second, the thrust developed by the rocket will be about 60,000 lb.

The firing of the rocket is carried out with the rocket in the vertical position. The rocket is placed in the vertical position while it is still empty and it is then filled with fuel. Before the actual filling, each tank is pressurised to 1.8 atmospheres for five minutes to check for tightness, after which the fuels are pumped into the rocket from mobile wagons.

The fuels are pumped in the following order:

Alcohol
Hydrogen peroxide
Liquid oxygen
Permanganate

The filling operation takes only 12 minutes, and it was one of the last operations before firing, as about 4.5 lb. of oxygen per minute were lost by evaporation, if the rocket was filled and left standing.

Two forms of igniting torch were tried, one a pyrotechnic torch (black powder) and the other a liquid operated torch, the former being preferred because it required less attention.

When the firing torch is alight, the main alcohol and oxygen valves are opened. These and the other valves throughout the rocket are operated by compressed nitrogen supplied from a bank of bottles situated in the power compartment, the same supply being also used to pressurise the auxiliary fuel tanks and force these fluids into their mixing chamber.

With the main fuel valves open 20 to 30 lb. of alcohol and oxygen per second are fed by gravity through the pumps to the combustion chamber, and is then ignited, the burning taking place without shock. Combustion is maintained for a few seconds, until an observer stationed at a distance is assured conditions are satisfactory, he then makes an electric contact which starts up the flow of auxiliary fuel, the turbine is started and is stated to reach full speed in about 3 seconds. During this time the flow of the main fuels to the combustion chamber increase, the thrust builds up, and soon exceeds the weight, causing the rocket to commence its vertical ascent. The whole operation, from the instant of firing the torch, to the rocket unit being up to full thrust taking only from 7 to 10 seconds.

Control

For maximum range it is necessary to turn the rocket on to its course and rotate it from the vertical until it takes up an angle of about 40 to 45° to the horizontal, by the time it has reached the all burnt stage, i.e., after 60 seconds flight. To do this the rocket is fitted with four graphite controllers, that are symmetrically placed around the exit of the jet, and four external controllers that are carried at the tips of the stabilizing fins.

The internal controllers are each operated by separate electric-hydraulic servo units. The two internal and external controllers which lie in the plane of rotation of the turbine rotor, being connected through a claw fitting; each internal controller and its corresponding external controller operating in the same sense. Electrical coupling is provided between the two servos driving these controllers, such that the controllers can be employed to provide roll and azimuth control.

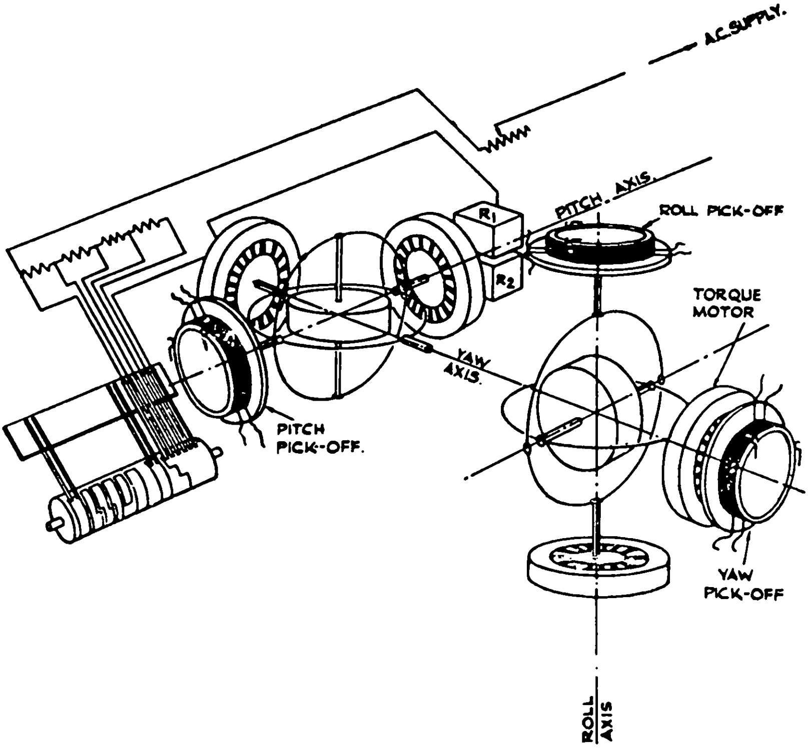
The other controllers, i.e., those lying in a plane at right angles to the plane of the turbine rotor, each has a separate drive, these drives are, however, electrically synchronised so that all the controllers move up or down together, and control the movement in the pitch plane.

The form of the control unit has undergone a good deal of change since the first rockets were fired against this country, but broadly all systems attempt

(1) Having set up the rocket with the plane of the turbine rotor lying in the plane of the target, to maintain the rocket axis in this plane.

(2) Stabilize the rocket in roll.

(3) Rotate the rocket axis in pitch at some predetermined rate.



—Crown Copyright

Fig. 4. Diagram of the automatic pilot used to control the motion of the A4 rocket in flight.

(4) Obtain some measure of the rocket velocity, and so enable the main fuel to be cut off at some point dependent upon the desired range.

When setting up the rocket for firing it was placed on a small horizontal turntable and the table was rotated so as to bring the pitch axis of the rocket perpendicular to the plane containing the target. This setting up was done by surveying methods. To control the motion of the rocket, in azimuth, roll and pitch, an automatic pilot was fitted. One form of this pilot comprised two electrically driven gyros, one with its axis along the axis of the rocket, and the other with its axis perpendicular to the axis of the rocket, and to the plane containing the target. This second gyro detects the roll and yaw of the rocket, but is unaffected by the pitching motion; the roll and yaw is measured by means of two fine wire potentiometers, and their outputs after passing through an electronic amplifier operate the controllers and so restore the rocket to its correct course.

The other gyro provides a pitch control, and during flight this gyro is made to precess towards the horizontal in the roll and yaw plane, and as in the case of the roll and yaw gyro, the movement is detected by means of a fine wire potentiometer, the output from the potentiometer is fed into an amplifier, and is then made to operate the controllers through their appropriate servos. The pitch control unit consists of five independently adjustable resistances in series with the pitch descriminator coil. Four of these resistances are initially shorted, and as they are brought in in succession, they give five different rates of precession to the gyro.

In some of the early rockets this function was carried out by the rotation of a drum switch driven by a constant speed motor and contained within the pitch gyro case, but in later versions the leads are led out of the case to an external switching device.

One unit that has been examined was set to precess the gyro, and so turn the rocket in the following way:

Time from start in seconds.	Angle.
0	90°
2.0	90°
8.5	80°
11.5	76°
28.5	60°
47.0	46°
52.0	44°

The rocket would therefore be turned from the vertical through 46° in 52 seconds.

The amplifier fitted into the rockets provided for differentiation of the input signal and so introduced a rate term into the control; it also provided for the mixing of the roll and yaw signals so that both functions could be controlled by the one set of vanes; a feedback from the pitch control vanes also ensured their synchronisation.

The automatic pilot, just described, meets three of the requirements mentioned above, leaving the control of range still to be taken care of.

In examining the question of range, it can be shown that in the case of a rocket traveling with its axis at about 45° to the horizontal, the range is dependent primarily upon the height and speed, and is not very sensitive to small variations of the actual angle. Furthermore, if the thrust characteristics of the rocket motor are reasonably repeatable, the height and velocity during the initial part of the flight will be related, since the pitch gyro will control the rocket path against time. It follows, therefore, that if the velocity can be measured, control of velocity can be used to control range.

This has been the basis of the method employed and early rockets contained two radio sets, one a receiver transmitter, and the other a receiver for velocity measurement and range control. The velocity was measured by a doppler effect, a signal sent out from the ground was received and retransmitted by the rocket at twice the received frequency. By doubling the outgoing signal and beating it with the returned signal, a beat frequency was obtained which is a direct measure of the rocket velocity. When the rocket reached a velocity which was dependent on the range desired, a signal was sent to the second receiver in the rocket, and this caused the turbine to be shut down, the fuel supply was therefore cut off and the rocket proceeded without further control rather like a shell fired from a gun.

Elaborate security arrangements were built into the radio circuits, so as to prevent the rocket motion being influenced by false signals.

The radio method of measuring velocity was soon dropped in favour of an integrating accelerometer, which was carried in the rocket, and so made the rocket self-contained and independent of any ground control from the moment of taking off on its flight.

The integrating accelerometer consists of a pendulous gyro mounted in gimbals and operating two sets of contacts whose angular separation can be varied. The gyro case carries a centralising switch, the leads of which run to a reversible induction motor geared to the gimbal. Any deviation from the mid-position of the gyro axis causes a torque to be applied to the gimbal in the sense appropriate to precess it back again. Because the centre of gravity of the gyro does not lie on the axis CD, any acceleration of the system parallel to the axis EF. i.e., the rocket axis, will cause precession about this axis at a rate proportional to the acceleration. The angle of precession will be proportional to the integral with respect to time of all accelerations, including any component of the earth's gravitational field acting in the direction EF.

Rotation of the outer gimbal, which actuates the contacts, therefore represents the value of the quantity.

$$\int\left(\frac{dV}{dt}+g\sin\theta\right)dt$$

$$\text{i.e.,}\quad V+g\int\sin\theta dt$$

and so affords a measure of the rocket velocity; 0 being the angle of the rocket axis to the horizontal.

The contacts can be made to control one function in the ground installation at starting, and two functions, slightly separated in time, when the quantity above has reached a preset value.

These functions are thought to be opening up to full thrust at take-off, and throttling first to about 1/3 thrust, and finally to zero thrust when the required velocity has been reached.

The shutting down from full to 1/3 thrust took about two seconds and was done to avoid difficulties due to "water hammer," the final shutting down to zero thrust took a further two seconds, and these times had of course to be taken into account in setting the contacts on the integrating accelerometer.

Characteristics Of Trajectory

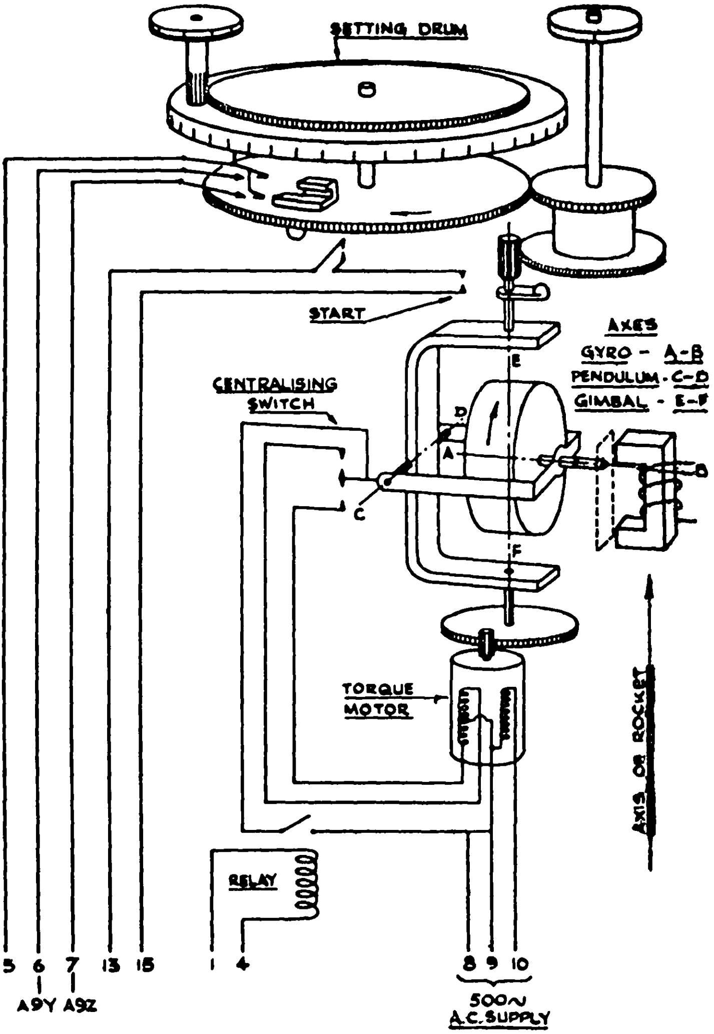
The early path, during which the motion is controlled by the pitch gyro is very nearly an arc of a circle, the rocket reaching a height of 22-23 miles and a velocity of about 5000 ft. per sec. (3400 m.p.h.) after about 60 seconds flight, as it is nearing the all burnt condition.

It should be noted that during most of this period it is the internal controllers that provide the main control. At the start of the flight there is no forward velocity over the external controllers, so they cannot exercise any control, while near the all burnt stage, although the rocket is moving at about 5000 ft. per sec., the relative density has fallen to 0.0053 and the indicated air speed is only 360 ft. per sec., so that again the control provided by the external controllers is small. At some intermediate height when they are effective, the inner controllers are equally effective, and can provide all the control that is necessary so that it is a little difficult to understand why the Germans went to the complication of fitting these external controllers.

After "all burnt" the rocket path is parabolic, and the velocity falls as the height increases, the maximum height reached being about 60 miles. How small the forces on the rocket are at this height can be judged from the fact that near the top of its trajectory the indicated air speed falls to about 3.5 ft. per sec., although the rocket is still traveling at nearly four times the local speed of sound. Once over the top the speed again rises and reaches a second maximum as the rocket moves into the denser air.

The actual operational range of rocket varied widely, a few rockets traveled as far as 220 miles, but most of them averaged 180-190 miles. Since the main path is parabolic, the height reached will always be about quarter of the range.

The total time of flight is about five minutes. The highest acceleration reached, which is at all burnt, when thrust had risen to 69,000 lb. and the



—Crown Copyright

Fig. 5. A diagram of the integrating accelerometer which superseded the radio method of measuring velocity.

weight has fallen to 8900 lbs., is just under 8g.

The highest velocity reached is at all burnt, the rocket is then traveling at 5000 ft. per sec. and it is interesting to note that at this velocity the rocket motor is developing well over 600,000 horsepower. The stagnation temperature corresponding to a velocity of 5000 ft. per sec. is about 1400°K, and in view of this it might be expected that the skin temperatures of the rocket during flight would tend to be high and approach the stagnation value.

To check this point a careful examination of the rocket skin was undertaken, and both from an examination of the condition of the paint, and a metallurgical examination of the skin material, it was concluded that the skin temperatures had not exceeded about 900°K. This figure agrees very closely with measurements that the Germans were able to make on an actual rocket in flight. In their tests the Germans inserted small discs of various metals of known melting point into the skin of the rocket and connected these into electrical circuits. As each disc melted, a signal was transmitted by telemetering to a ground station. It was found that the skin temperatures nowhere exceed 920°K, conduction and radiation losses therefore must have kept the skin temperature down well below the stagnation temperature.

In the course of our investigation into the A4, calculations were made to determine the stability of the rocket during its passage through the upper atmosphere. Two cases were considered, one in which the initial rate of pitch and rate of change of pitch angle were equal, and the other in which the initial rate of pitch was zero. The calculations were confined to a consideration of the behavior of the rocket after all burnt, and assumed that the rocket velocity was then 4960 ft. per sec, the height 22.8 miles, and the rocket axis made an angle of 41.3° to the horizontal.

It will be seen from the figure that under both assumptions, the rocket developed a pitch oscillation, which is undamped on the upwards parts of the trajectory, but which is quite heavily damped as the rocket descends into the denser atmosphere. The motion is never very large, and in neither case does the rocket incidence exceed 2.5° to the line of flight.

Other Rocket Developments

There were in addition to the A4 rocket just described a large number of other rocket developments going on in Germany. The A9 for example, was an A4, equipped with wings, permitting it to glide when it reached the stratosphere, with a view to increasing the range.

A10 was a still more ambitious rocket, in the project stage only; it was to weigh about 85 tons, and was intended to carry the A9 rocket into the stratosphere, and then be jettisoned, A9 and A10, therefore, were separate stages of a two-stage rocket.

Towards the end of the war, when Germany was in serious difficulties because of the Allies' very heavy bombing attacks, a great deal of attention was given to defence against these attacks and work on a large number of ground to air rocket weapons was started.

The number of these schemes started up seems to be closely related to the number of people with "bright ideas", and "Enzian," "Wasserfall," "Taifun," "Rheintochter," "Schmetterling" are some examples.

Two other rocket applications, also intended as a defence against bombers, are the Me163, and "Natter." These are interesting because both were piloted, though in the case of "Natter" it was intended that the pilot on the completion of the attack, should abandon the aircraft and land by parachute.

The Me163 is built around the Walter (T stoff C stoff) rocket unit. This unit, which weighs 415 lbs., develops a thrust of 3740 lb. for a fuel consumption of 20.5 lb., the fuel therefore has a specific thrust of about 180 lb. per sec. In one particular unit a small cruising jet has been embodied so as to give the aircraft a longer endurance.

The Me163 is a tailless aircraft, it has a span of 30.5 ft., a length of 18.7 ft. and a gross wing area of 211 sq. ft. The Me163C, which is the aircraft fitted with the cruising jet motor, has a take-off weight of 11,300 lb., of which 5570 lb. is fuel. The aircraft is estimated by the Germans to have a top speed of nearly 600 m.p.h. and it could climb to 40,000 ft. in just over three minutes. In doing this it practically exhausted all its fuel, since at full power the fuel only lasted about 4.5 minutes.

"Natter" the other piloted rocket aircraft was intended to be catapulting at an angle of 75°, by means of two solid fuel rockets, which were to be jettisoned at a height of about 5000 ft. A T stoff C stoff rocket motor then took over, and the aircraft continued to climb to the desired height, this should have brought the aircraft into the bomber formation and the pilot after completing his attack dived away and abandoned his ship.

The feature of both these rocket propelled aircraft is their high rate of climb. This was a feature which it was hoped would make it possible to defend a target with little warning of the impending attack, a feature that did not make it necessary for the aircraft to be in the air, except when carrying out an attack, and it was on a consideration of this kind that the very short endurance was justified.

Factors Affecting Rocket Performance

In discussing rocket performance it is useful to introduce the ratio

$$\frac{\text{Fuel weight}}{\text{Total weight}}$$

which is often referred to as the "x" of the rocket.

The x in the case of the A4 rocket is about 0.69, that is to say, more than two-thirds of the rocket weight is given up to fuel.

Effect Of x On Range

Now for the effect of x on range curves being drawn for a series of rockets of different all up weights. It will be seen at once that variations of x have much more influence, on range, than variations of size; a 50 per cent. increase in the all up weight for the same x, only increasing the range by about 10 per cent, whereas only a 2 per cent. change in x is required to produce the same effect.

It is interesting to observe that if the 2150 lb. of warhead, carried by the A4 rocket, were replaced by fuel, x would have increased to 0.76, and the range would then have been about 350 miles. Since an x of 0.76 probably approaches the limit of what it is practical to achieve, it is clear that the range of a single stage rocket of the kind we are discussing is fairly limited.

Effect Of Fuel On Range

The limitation in range, that we have just considered, at once raises the question of whether some better fuel giving an improvement in specific impulse might not be possible.

In the influence of the specific impulse on range it will be observed that an increase in the S_I from 215 to 298 would double the range of the rocket. Against this, however, it must be remember that improved S_I of a given fuel can only be had at the expense of greatly increased working temperatures and pressures of the gases in the combustion chamber. Practical consideration of the loads coming on the combustion chamber will therefore limit what is possible to achieve in this way. In passing, however, it should be noted that the working S_I of a rocket fuel does not improve with altitude, as a consequence of the increased pressure ratio across the venturi as the atmospheric pressure falls off.

The other course open to the rocket designer to improve range is the choice of different fuels; here the heat of combustion of the fuel and the molecular weight of the resulting products of combustion are the important factors. Table II gives the specific impulse of a number of fuels, calculated on the basis of working conditions cor-

Table II.
Specific Impulse of Various Fuels

Fuel	Volume Ratio	K° Combustion Temperature	y	Molecular Weight	Specific Impulse
Ethyl Alcohol and Oxygen	1:1.15	2,780	1.2	20.0	235
Petrol and Oxygen	1:1.4	2,240	1.3	16.5	224
Hydrogen and Oxygen	1:3.2	2,560	1.2	8.4	343
Hydrazine Hydrate and Hydrogen Peroxide	1:2.03	1,750	1.2	24.0	200

responding to the venturi characteristics of the A4 rocket.

Most practical values of the S_i lies between 180-240, but it will be seen from the table that by using hydrogen and oxygen the value could be pushed up to well over 300 while still retaining a moderate combustion temperature, and some still further improvement in this S_i would be possible at the expense of the working temperatures and pressures.

Variation Of Range

The range is also influenced by the rate of burning of the fuel, i.e., on the thrust developed, and therefore on the accelerations experienced during the initial stage of the flight. It will be observed that the effect is not large, but nevertheless variations of the order of + or — 10 per cent. in range are possible, and it is important therefore to take this factor into account when deciding on the venturi and fuel pump design.

Conventional Aircraft And Rocket

It is perhaps as well at this stage to pause and make a brief comparison between a conventional aircraft and the rocket or the rocket propelled aircraft as developed by the Germans. In the following table the main characteristics of a fairly representative high speed bomber are compared with those of the V2, and as a matter of interest the corresponding figures for the V1 are also included.

Table III.
Comparison Between Conventional High Speed Bomber and Rocket

Item	Fast Bomber	V2	V1
Percentage Weights			
Structure	29	13	25
Power Plant	24	8	8
Fuel	19	69	19
Equipment	13	2	1
Pay Load	16	8	46
Speed in Miles per hour			
Take-off	120	0	200
Maximum	400	3,400	350-400
Other Data			
Ceiling (ft.)	40,000	350,000	9,000
Range (miles)	1,600	220	175
Endurance (min.)	390	5	30
Fuel Consumption (lb. per sec.)	0.57	275	0.66
Fuel Consumption (lb./h.p. hr.)	0.75	1.6	4.3
		(at near all burnt)	

The item in the weight comparison that attracts attention is the high pay load of the VI, and the low pay load of the V2. As might be expected, the percentage structure weight of the V1 does not differ greatly from that of a conventional aircraft, but the light power plant and the small amount of equipment carried has enabled the pay load to be high. The V2 on the other hand, although it gains on account of the light form of power plant, and a very small structure and equipment weight is handicapped by the very large amount of fuel that has to be carried.

Another point of particular interest is the fuel consumption figures, expressed in lb. per horsepower hour. The V1 engine is very uneconomical,

Table IV.

Comparison Between Typical Fighter and Me163C Rocket Plane

Item	Typical Fighter	Me163C
Percentage Weights		
Structure	30	25
Power Plant	38	9
Fuel	12	49
Equipment	10	4
Pay Load	10	13

and the fuel consumption, expressed in this way, is at least five times greater than a more normal petrol engine, but the V2 on the other hand at near all burnt, which is of course the most favorable condition, does achieve a consumption figure that is only twice that of the conventional engine.

Table IV makes a further comparison, this time between a typical fighter aircraft and the German Me163C.

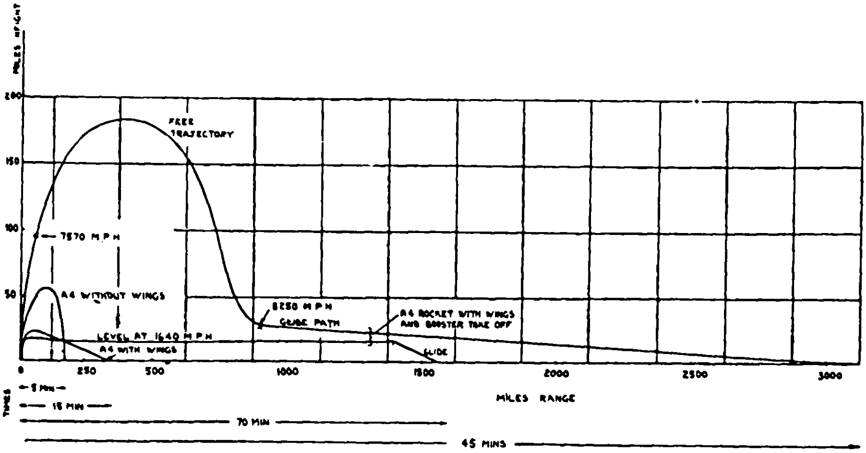
Here again the light power plant, and the light equipment weight of the rocket plane are offset by the very large amount of fuel that has to be carried, the pay load however has not been sacrificed, and as was pointed out earlier, although the top speed and climb performance of the Me163 are high, the endurance is very short.

The Future

At this point in a lecture of this kind, I think the lecturer is entitled to embark upon a little speculation regarding the future. I have attempted, during the course of the lecture to set up one or two signposts, which give an indication of some of the possibilities and some of the limitations of rocket propulsion.

Ten years ago, when it was only the very fast aeroplane that traveled at 400 miles per hour, we were still speaking of a "sonic barrier," and we were attempting to predict the speed which, so to speak, would mark the limit of man's endeavour.

The rocket motor, with its light weight, and its very large thrust per square foot of frontal area, has now made flight at speeds well into the supersonic range possible and a few calculations have been made, which illustrate some of the possibilities. Starting with the A4 rocket, we have assumed that the warhead is removed, and replaced by a pressure cabin and pilot, and in addition, the rocket is fitted with wings; the wing area being arranged to provide for a landing wing loading of 35 lb. per sq. ft.



—Crown Copyright

Fig. 6. Trajectories of rockets with wings compared with the wingless A4.

Three cases will be touched on briefly. In the first, the A4 rocket with wings is assumed to be fired vertically, and controlled in the same manner as a normal A4 rocket until it reaches the top of its trajectory, when the pilot takes over and glides the rocket to the ground along its optimum glide path.

In the other two cases, the A4 rocket with wings, has been assumed to be taken up by means of a booster rocket rather on the lines of the German A10 project mentioned earlier in the lecture. In this way the rocket reaches a height of 80,000 feet before being released at a speed of 3000 m.p.h. (these conditions corresponding to the height and speed reached by the A4 rocket with wings at all burnt, when it is fired vertically upwards in the normal way). From this point onwards the rocket with its full fuel continues the flight, and in the first of these boosted cases it has been assumed that the rocket venturi is redesigned, and now provides a thrust corresponding to level flight at 1640 m.p.h., at 80,000 feet, while in the other the redesigned venturi provides a thrust which enables the rocket to continue the climb. The results of these calculations are compared with the traiectory of the normal A4 rocket without wings.

The first striking thing about the results is the effect that the addition of wings has on range. The range of 180 miles of the normal A4 rocket without wings has now been raised to 350 miles.

Still more striking however is the effect of the booster on the general performance. Ranges of 1500 to 3000 miles now appear to be possible, and the advantage of continuing the climb at the end of the booster stage is also very marked. It is interesting to note that with a rocket boosted in this way it would be possible to complete the journey from London to New York in well under the hour.

The first of the two cases of the rocket with wings presents no problem that is outside of the experience already gained by the Germans during their work on the A4 rocket, the third case however does raise many new problems. It contemplates for example flight at over 8000 m.p.h., this means a stagnation temperature of nearly 7000°K, so that even though radiation may play an important part in keeping the temperature down, the pilot would nevertheless find himself enclosed in a body the skin of which, to say the least of it, was uncomfortably hot. Over a large part of the flight too, the rocket would be moving on a free trajectory, since the wings cannot provide sufficient lifting force to control the motion. Over this part of the trajectory the pilot would be subject to zero g, and it would not be until the rocket returned to a point about 28 miles above the earth's surface that the pilot could begin to assume control of his machine.

The booster contemplated in connection with these schemes would of course be very large; it would certainly weigh about 100 tons, and the Germans in planning their schemes had hoped that the booster after being jettisoned, would be recoverable.

The results of the calculations that have just been outlined are admittedly very sketchy, but they do, I hope, give some indication of the way in which it may be possible to fly at supersonic speed. I do not however want to minimise the difficulties of this problem. As yet nothing, or practically nothing, is known about control at these speeds, nor of the difficulties that will be encountered in passing through the speed of sound. The vertical ascent at the beginning of the trajectory avoids some of these issues, while for control over a greater part of the flight through the upper atmosphere it is quite likely that the controllers will have to be in the form of small rocket jets, since the external forces called into play are far too small to affect the motion. These, however, and the many other problems are matters that will have to be left to the future.

Concluding Remarks

I should like in conclusion to say how much I am indebted to the many workers in this field who took part in the A4 rocket investigations, on whose work I have drawn quite freely in preparing the present lecture.

I would also like to emphasize that all opinions expressed in this paper are my own and do not necessarily represent the opinions of the R.A.E. or the Ministry of Aircraft Production.

Table V
Approximate Conditions in Venturi

	Chamber	Throat	Exit
Diameter (ft.)	3.11	1.32	2.41
Pressure (lb./in^{2}ABS)	294	157	14.7
Temperature (°K)	3000	2670	1650
Velocity (ft./sec.)	0	2000	7000

Appendix I
Detail Summary of Weights of A4 Rocket Components

Warhead (with Amatol filling)	2150 lb.
Radio and Instrument Bay	
Radio compartment including end frame	325 lb.
Radio equipment including mountings	155 lb.
Instruments, electrical equipment and wiring	415 lb.
Compressed nitrogen bottles and fittings	80 lb.
	975 lb.
Tank Bay	
Shell structure around tanks (including glass wool)	1185 lb.
Oxygen tank and fittings	375 lb.
Alcohol tank and fittings	235 lb.
Liquid Oxygen (tank full)	10940 lb.
Alcohol (tank full)	8370 lb.
	21105 lb.
Power Unit Bay	
Steel structure around power unit	410 lb.
Auxiliary power unit mounting and end frame	260 lb.
Auxiliary power unit	880 lb.
Pipes and valves	70 lb.
Venturi, including burner assembly	1025 lb.
Hydrogen Peroxide (T Stoff)	370 lb.
Sodium permanganate	29 lb.
	3044 lb.
Control Surfaces	
Stabilising fins	750 lb.
Internal control vanes, including servo units	470 lb.
External control circuits	115 lb.
	1335 lb.

Appendix II.
Performance Details of Rocket Propulsion System

Turbine	
Mean diameter of blades and nozzles	18.5 ins.
Main flow through turbine	3.5 lb./sec.
Working pressure	330 lb./in.^{2}
Turbine back pressure	1.6 lb./in.^{2}
Estimated power	680 h.p. at 5,000 r.p.m.
Endurance at 3.5 lb./sec.	113 secs.
Main Fuel Pumps	
Oxygen Pump	
Overall impellor diameter	10.55 ins.
Flow at 5,000 r.p.m.	160 lb./sec.
H.P. at 5,000 r.p.m.	320
Delivery pressure	350 lb./in.^{2}
Alcohol Pump	
Overall impellor diameter	13.45 ins.
Flow at 5,000 r.p.m.	125 lb./sec.
H.P. at 5,000 r.p.m.	360
Delivery pressure	370 lb./in.^{2}

Assuming that 5 per cent. of the alcohol is used inefficiently as coolant, and 5 per cent. returned by the spill valve to the lower pressure side of the pump.

Total fuel delivered to combustion chamber	275 lb./sec.
Specific thrust	220 lb./sec.
Total thrust	60,000 lb. (27 tons)
Capacity of main tanks	19,300 lb.
Endurance at full flow	70 secs. (approx.)

Rocket-Propelled Interceptor Fighters

The Walter HWK 509 Rocket Unit

By E. BURGESS

Towards the end of the European conflict, German technicians developed many rocket propelled and remotely controlled missiles which may have proved extremely embarrassing to Allied bombers if the war had continued. It is the intention of the writer in this article to discuss the technical aspects of the Walter HWK 509 bi-fuel rocket unit and the two main types of aircraft in which it was employed.

Motor Construction

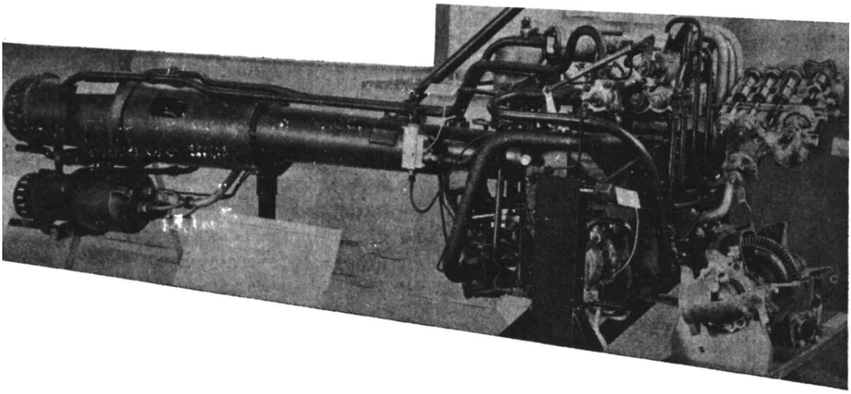
This motor was of the regenerative type, and fuel was injected by 17 fuel injectors situated at the head of the motor, somewhat similar to the idea employed in the V2 except for the absence of definite burner cups. Construction was of mild steel, with a double wall to the combustion chamber and part of the nozzle. Swirl vanes were included in the coolant space so as to ensure efficient circulation of the fuel over the surface of the liner. Only one of the comburants was used as a coolant. The throat diameter of the motor was just under 4 in., the overall length of the motor and short expansion nozzle was approximately 2 ft., and the unit scaled 365 lbs.

Feed System

Coupled with the actual motor itself was a rather complicated fuel feed arrangement which enabled five varying powers of thrust to be obtained. The highest of these thrusts was 3300 lbs. which, at a speed of 600 m.p.h., represents a horsepower of just over five thousand. The Rolls-Royce Derwent V jet-propelled engine, by comparison, is reported to give a thrust of 3700 lbs. approximately. The minimum thrust of the HWK 509 unit was only 220 lbs.

At maximum thrust the jet flow was around 1000 lbs. of fuel per min., and this therefore signifies a jet velocity in the neighborhood of 6400 ft. per sec.

The connection between the motor and the pumping system and fuel metering system was made by a number of pipes enclosed in a cylindrical casing about 4 ft. long. The fuel pumping arrangements consisted of



Flight

Fig. 1. The HWK 109-509 bi-fuel unit as used in the Me 163C.

two fuel pumps connected to a turbine which was driven by superheated steam generated from one of the fuels.

Fuels

Two liquids, designated "T-stoff" and "C-stoff", were the fuels employed. The former was an 80 per cent solution of hydrogen peroxide as used in the V2, and the latter consisted of a hydrazine hydrate solution in methanol. Not only did the hydrogen peroxide act as a component of the rocket fuel, but it was also used to give steam for operating the fuel pump turbine. A part of the liquid, after passing through the pump, was tapped off and passed into a container which housed a catalyst. Starting was accomplished by means of an auxiliary electric motor which sent fuel through the system sufficient to enter the catalyst chamber and thus start the turbine. The hydrazine solution was employed as a coolant and circulated around the combustion chamber and nozzle throat before being injected at the head of the chamber. No pre-mixing of the fuels took place before injection, and control of the number of injectors operating at any time determined the thrust at that instant.

The design of the motor was attributed to a Dr. Walter, who worked at Keil, but it was later developed by other companies including the Junkers corporation. The main types of aircraft in which it was used were the Me 163 and BP 20, both being high speed, short duration, interceptor fighters. A similiar, but smaller unit was employed in the Hs 293 and other types of glider bombs although some later models in that series were adopted for use with solid fuel rockets.

Me 163

It was during one of their mighty daylight raids over the territory of the Third Reich, that American bomber fleets first met the Me 163 tailless aircraft. Pilots reported bird-like machines shooting past the bomber formations too quickly to be closely observed. This aircraft, known as the Me 163 "Komet," was the first aircraft to be propelled by a liquid fuel rocket motor, and was the first operational rocket plane. General details of the physical characteristics of the airframe have appeared previously in this Journal, but it is interesting to recall its exceptional performance. The aircraft was capable of a level speed of up to 600 m.p.h., and has been known to travel at 625 m.p.h. under test. It could climb to an altitude of 30,000 ft. in 2.6 minutes. The great disadvantage was, of course, the short duration of the powered flight. Due to the unstable nature of the fuels it was also necessary to scavenge the motor and jettison all remaining fuel before attempting to land. Piloting this type of aircraft could, indeed, be a very hazardous operation.

From the original aircraft were developed the Me 163B and Me 163C. The latter had an auxiliary rocket motor beneath the main unit and which was included to economise in fuel while cruising. This double combustion chamber HWK 109-509 unit is the one shown in the photograph. Finally development was taken over by Junkers, which firm ultimately produced the Ju 248. Again this was later modified by Messerschmitt and became the Me 263.

Ju 248

The Ju 248 was of slimmer design than the Me 163, and it incorporated a retractable tricycle undercarriage which replaced the landing skid and tail wheel of the earlier models. The auxiliary combustion chamber of the Me 163 was retained to conserve fuel, and continued to be mounted beneath the main unit. Performance was, however, considerably improved, and the Ju 248 was stated to have been designed for reaching an altitude of 40,000 ft. in three minutes.

(Continued on Page 23)

Construction And Performance Of The Baka

Japanese Jet-Driven Suicide Bombs

By WALLACE J. OSBORN, Jr.

The Baka is similar to an oversize torpedo in appearance with a stubby double tapered mid-cantilever-wing and a high set rectangular tail plane, at the ends of which are located rectangular fins and rudders. Just aft of the mid-point of the fuselage is located a bubble type canopy.

The finish of the craft is excellent, clean and quite simple. Shapes and proportions of the bomb are not unlike those of the German Hs 293 radio-controlled bomb. Wing span of the Baka is 16 ft. 5 in. and overall length is 19 ft. 11½ in. The wing has a slight dihedral of about 2°3' and is set at approximately a zero angle of incidence, with the root chord of 58½ in. sizeable in proportion to its span. Dimensions of the square cut twin fins and rudders are 1 ft. 11 in. by 2 ft. 2 in. The tail cone forms a downward sloping angle and is completely open at the aft end to allow the three rocket tubes to project slightly.

Area for both ailerons is 3.2 sq. ft. and the wing loading for the craft is approximately 70.2 lbs. per sq. ft. (assessing 800 lbs. for the three rocket units).

The Baka is constructed in the following five major assemblies:

1. Warhead and warhead fairing.
2. Central fuselage.
3. Wing.
4. Tail unit.
5. Rocket installation.

Warhead

Total weight of warhead is 2645 lbs., length is 68⅜ in. and diameter 23⅝ in. It contains 1135 lbs. of trinitroanisol and is equipped with five fuses, one nose and four base fuses.

The body is a machined forging made in one piece with a wall thickness varying from 13/16 to 2½ inches. The first 5 7/16 in. of the nose is solid. A hole is bored in the nose for a standard nose fuse and a set screw is provided to lock the fuse in place after the assembly. The internal surfaces of the body and base plate are heavily lacquered to prevent contact between the explosive filling and the metal.

An aluminum plate 1⅜ in. is placed in the front end of the body directly behind the base fuses. This acts as a cushion and prevents the detonation of the explosive by the shock of impact. This allows the warhead to pierce the armored hulls of ships.

Central Fuselage

The central fuselage is constructed of aluminum alloy and is of semi-monocoque construction. The fuselage skin is about .025-.040 inches in thickness and flush rivets are used throughout except for a section in the region of the empennage.

A mounting for the warhead is built of welded steel tubes 1.75 and 2.00 in. in diam. and ties into the four longerons. Four warhead support points are provided.

Aft of, the cockpit, on the bottom of the center fuselage section, twin-rail type supports are fitted for the support of two of the rocket units. The third rocket unit is suspended from the top by two lugs on a fifth (false) longeron. There are eleven circular shaped bulkheads between the base of the bomb and the tail of the fuselage, with an average spacing of 15 in.

Wings

The wings are made of wood incorporating high density wood beams at approximately the 20 and 60 per cent chord points. The leading edge

Table I
Dimensions of the Baka

Wing Span	16 ft. 5 in.
Length (less nose fuse)	19 ft. 10 in.
Span, tail plan	7 ft. 1 in.
Wing area	64.7 sq. ft.
Aileron area (both ailerons)	3.2 sq. ft.
Wing loading (approx.)	70.2 lbs./sq. ft.
Max. height fuselage, nose section	2 ft. 6½ in.
Max height fuselage, including canopy	3 ft. 10¼ in.
Max. height fuselage, tail section	2 ft. 3¾ in.

is made of 5 ply wood and held in shape by ribs with approximately a 12 in. spacing, and the trailing edge is of similar construction. The ailerons are also of wood, mass balanced push-pull controlled, with leading edges normal to the longitudinal axis. All plywood surfaces are fabric covered, and an electrically heated pitot tube is fitted to the port wing.

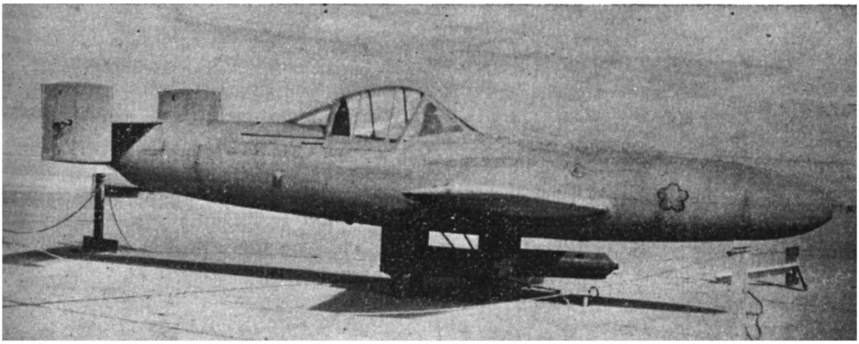
Tail Unit

The end section of the fuselage, which in assembly is bolted to the rear frame of the central section mounts the tail plane. This latter is made entirely of wood, fabric covered as are the twin fins and rudders, while the end section of the fuselage itself is of aluminum alloy (superdural clad and rolled) like the main fuselage section.

The narrow chord elevators and rudders are mass balanced and are cable controlled from cockpit to jack shafts near the aft end of the fuselage, beyond which push-pull tubes are used. Some of the models examined so far have small trim tabs fitted near the top of the rudders. Small cooling air scoops are fitted to the fuselage for ventilating the rear fuselage rocket compartment, and one small scoop ventilates the cockpit.

Rocket Installations

The propulsion unit has an overall length of about 7 ft. and with the exception of minor differences in mounting lugs, the fuselage rockets are all identical. The entire unit consists of three rockets projecting slightly aft of the open tail cone below the high set empennage. A single rocket consists



—AAF Photo

Fig. 1. Japanese Baka piloted antiship bomb. Uses three solid fuel rocket motors.

Table II
Weight analysis of the Baka

Fuselage with fairing	471.5 lbs.
Wing	367
Tail	120.5
Nose fairing	40
Plane weight (unloaded)	999 lbs.
Warhead	2645
Rocket unit	768
Pilot	120
Oxygen bottle	4
Total Weight	4536 lbs.

Table III
Physical characteristics of the rocket charge

Length of grain	500 mm (19.6 in.)
Outside diameter	110 mm (4.3 in.)
Diameter of single axial perforation	10 mm (.39 in.)
Weight	7.4 kg (16.2 lbs.)

Chemical Analysis

Nitroglycerine	26.9
Nitrocellulose (Nitrogen 11.54)	59.9
Graphite	Nil
Ash	2.8
Potassium sulphate	2.9
Ethyl centralite	2.9
Alpha-nitronaphthalene	6.1
Dinitronaphthalene	Trace
Total volatiles	1.3
Heat of explosion	820 cal/g

of a steel cylinder to which is welded at the front end a cone which contains the primary igniter; at the rear another cone is screwed into the cylinder and into this is screwed the nozzle. Welded to the nozzle and projecting backwards is the expansion tube. Weight of a single rocket without the propellant fuel is 160 lbs.

Internal parts of the rocket consist of (1) a grid at the front end of the cylinder to which is attached a flat circular bag of black powder which constitutes the igniting charge. (2) The propellant which consists of 6 grains arranged in tandem groups of three with a total weight of 98 lbs. per rocket and (3) the trap which is a perforated plate integral with the rear cone.

Rockets are ignited electrically by a selector switch which determines the order in which the three rockets are fired. The rockets provide a thrust of about 1500 lbs. for about 8-10 seconds each. The difference in the physical location of the three rocket tubes will cause a corresponding difference in the location at which thrust is applied with respect to the center line of the plane. This will probably cause some difficulty in control as each successive rocket is ignited.

Wing Rockets

It is believed that the possibility of wing rockets exists because a space was found on the selector switch marked "wing." Recessed mounting brackets were also found in the wings and this seems to suggest either the use of rockets or a ground-launching of the Baka. The mountings are so constructed that either type of device could be jettisoned.

It has been calculated however, that the additional drag caused by the mounting of wing units would almost offset their extra propulsive thrust and only increase the horizontal range approximately 2 miles when dropped from 27,000 ft. without materially affecting the speed.

Maximum Range

The flying bomb's maximum gliding speed in level flight is approximately 230 m.p.h. although the rockets greatly increase the Baka's speed for a short time, they cause only a slight range increase over the maximum glide range. The maximum horizontal range when released at 27,000 ft. is 55 miles. Fifty-two of these miles would be traveled at a glide speed of 230 m.p.h. and at a minimum glide angle of 5°35'; during the remaining 3 miles, the use of rockets would accelerate the speed to 535 m.p.h. in level flight. At a 50 per cent or greater diving angle, terminal velocity will be 620 m.p.h. with rockets.

Without rocket power the same speed would be reached at a diving angle of 88-90 degrees. Whether the rockets were used at the end of the run or whether they were used to climb, would not appreciably affect the maximum range. However, at very low temperature it is possible to increase the maximum range to 60 miles.

Other Devices

It has been revealed that the Japanese used a ground-launched, piloted suicide rocket bomb against B 29's over Japan. The craft in general resembles the Baka except that it is armed with two 20 mm. cannon firing forward through the nose. The plane also has a single fin and rudder, and a reinforced bottom on which rails are fitted. It is launched from a platform being airborne in approximately 100 ft. (takeoff run) and reaches an altitude of 32,000 ft. in about 3 min. The bomb can reach a maximum speed of around 500 m.p.h. in a gliding run on a target, and is capable of 7 min. maximum flight. Besides the cannon, the plane is also armed with a warhead which explodes on contact. The size of the warhead is probably much smaller than that of the Baka.

The bomb is rocket propelled but it is believed it uses a much more powerful motor (possibly a liquid-fuel type) and further maneuverability is added by selective rocket jets. The main drawback to the plane is the inability of the human body to withstand the rapid acceleration and climbing speed.

Another use of rocket propulsion which the Japs also used was the rocket assisted takeoff of overloaded planes. The propulsion unit is filled with slow burning gunpowder ignited electrically in three connected cartridges. Two units are on each plane, on the after part of the fuselage, near the vertical surface. The combustion time is 3 to 3.5 sec. and a carrier plane's takeoff can be reduced to about 66 per cent of the normal distance.

(Continued from Page 19)

The Natter

The BP 20 "Natter" was a product of the Bachem concern and an even more remarkable aircraft than the Me 163. It was really a man-carrying piloted projectile, with short stubby wings. The HWK 509 bi-fuel unit again supplied the propulsive power, but in addition, for takeoff purposes, four large solid-fuel rockets were used. The body and wings of the aircrafdt were normally constructed cheaply from wood, and the armament consisted of over a score of rocket projectiles which were stored in the nose under a streamlined fairing which could be jettisoned before the rockets were discharged.

For launching, the Natter was mounted on vertical launching rails, and under the influence of the liquid fuel and solid fuel rockets which together developed a thrust of nearly 8000 lbs., it ascended vertically at a high speed. The climb was actually at a rate of 37,000 f.p.m., but it was so arranged that the acceleration did not exceed 2¼ times that of gravity. The solid fuel rockets were jettisoned after the first few thousand feet of height had been reached, and although the aircraft could ascend to nearly 50,000 ft., the maximum speed of 620 m.p.h. was obtainable at an altitude of 16,000 ft.

The procedure employed was for the fighter to proceed vertically to the level of the attacking bombers, at which height it would then flatten out. On contracting the bomber formations, the pilot would jettison the streamline nose fairing and discharge the rocket projectiles. The duration of flight was not more than 5 minutes, and the aircraft could not glide when the fuel became exhausted. It was , therefore, necessary for the pilot to operate a control which ejected him and enabled his decent by parachute. At the same time, the Natter split in two sections

German Development In The Field Of Rocket Powered, Controlled Missiles

By LT. COLONEL JOE B. MAULDIN

Although the Germans recognized the potentialities of remotely controlled rocket or jet powered missiles during World War I and accepted them without equivocation as a military weapon over ten years ago, the science did not assume its current degree of exceptional importance to them until the latter stages of the recent conflict. When the necessity of stopping the Allied bombers became paramount, it was realized that the answer lay in guided missiles.

Germany, contrary to the reasoning of other countries, had not in any sense failed to lay the groundwork of fundamental research for producing a complete series of potentially satisfactory anti-aircraft controlled missiles; however, the basic work did not manifest itself as usable "flak" because the actual construction and experimental testing were neglected until too late. It is obvious now that the foregoing resulted from underestimation of the damage the Allied air forces could inflict, from a misconstrued confidence in their standard counter weapons which were even then obsolete, and from overconfidence in the damage, both physical and psychological, which their V-weapons were effecting.

Basic Policy

It is interesting to note that it was the ground-to-ground self-controlled missile, i.e., the V-weapon, which was selected to receive the lion's share of the energy devoted to testing and developing of guided missiles. Even in minds chained to the utility of conventional weapons, the obvious strategical employment of this type could not be overlooked. However, in selecting what at that time must have appeared to them a fantastic innovation, they did not recognize the implications pointing to related weapons which were to become vitally important.

It must be borne in mind that the magnitude of the German's basic research program was tremendous and that it was equally thorough for all types of controlled missiles. Once they realized the defensive potentialities of various types of this new weapon, a program was inaugurated, which if given six more months uninterrupted time, might well have resulted in the achievement of what had become a basic policy: to drive bombers from the sky at altitudes below fifty thousand feet.

Early Innovations

In justification of the above, the picture of the history and magnitude of German effort in this field is included. The idea of increasing the accuracy of a weapon by controlling it to its target was conceived during the first World War. This thought manifested itself in the form of an aerial bomb guided in range and azimuth by signals transmitted down a wire which unreeled as the missile fell. Projects related to the above lay dormant until World War II, when the modern controlled missile program made its appearance in the form of the FX high angle bomb and the Hs glide bomb series in the Mediterranean. However, the intervening time was not wasted, as it was during this period between wars that the experimental rocket groups were most active. One faction of these groups later formed

---

Excerpts from address presented at the Regular Meeting, American Rocket Society, New York, December 14, 1945.

the nucleus of the Peenemunde personnel, whose sole function was the research, development, and testing of rocket powered controlled weapons.

The FX and Hs missiles were predicated on the assumption that the Luftwaffe would maintain air supremacy and while this condition existed they were used to good advantage. The Allies counter measure, jamming, did not put an end to the use of Strassburg-Kiel radio control unit, but it did succeed in stimulating the enemy's thought and subsequent development activ--ities relative to new control systems. Their first reaction was the return to the wire control method of transmitting intelligence. This was closely followed by programs designed to cover all eventualities.

Anti-Aircraft Missiles

With the increase in Allied air power, Axis interest began to focus on the development of controlled anti-aircraft missiles. This interest grew rapidly and a highly competitive development program for AA missiles expanded with the steady increase of Allied aerial might until at one time in 1943 there were under development in Germany 48 different anti-aircraft missiles. To counteract the increasing abuse Allied air power was delivering to German industry, it was necessary to streamline the program to produce greater emphasis and efficiency. Therefore, the 48 different anti-aircraft development projects were surveyed and after an analysis as to completion of development and effectiveness of the missiles, all but 12 of the 48 were discontinued. The remaining 12 were to be carried through to full development for operational use.

V1 Weapon

During the period of growth of the Allied air power, the heretofore visualized need of long range remote controlled or self controlled missiles for area bombing became an actual necessity. Resulting from the successive defeats, the Luftwaffe was suffering, it became less and less advisable to send bombing squadrons against the enemy; therefore, increased effort was placed on the development of supersonic missiles which were visualized as early as 1936 as potential weapons. These were hastily and prematurely thrown into the fray. In addition to the development of long range supersonic weapons, there was simultaneously carried out through developmental to operational use, the V1 weapon or "buzzbomb". The V1 was the first long range missile operationally used as a self-contained, non-piloted guided or controlled weapon. It is estimated that over 20,000 of these were used against the Allies.

As a substitute for the V1, the BV series of glide bombs were developed as an inexpensive long range (100 miles) bomb for area bombing. Approximately 400 of these were built and tested, but they were never put to operational use due to a shortage of suitable bombers to carry and launch them.

A Series

During this same period, the development of the A series, i.e., V2 missiles, for supersonic speed ranges was carried on in spite of continual handicaps caused by Allied bombings. A large modern well-equipped missile development and testing center was established at Peenemunde on the Baltic Sea. This station which cost 300 million gold marks for the initial installation was started in 1936 and was reported in operation in 1937. Regardless of Peenemunde's tremendous size and its influence on the program, it in no way portrays the extent of the energy being exerted by other governmental agencies and commercial firms within the Reich. After the expenditure of a tremendous amount of money and energy on this project, the A4 missile went into operational use in 1944. It is estimated that 3000-5000 of these missiles were built.

To increase range, the A4b was made by the simple addition of wings to the A4. This approximately doubled the A4's range. With the ultimate operational range in sight for the A4b design work was immediately started on more radical weapons. There is little of humorous nature in the statements so often heard that the Germans intended to bombard New York from launching sites in Europe, as two missiles, the A9 and A10, were under development for use against the U. S. in the early months of 1946. This contemplated use was scientifically possible and undoubtedly would have been realized had time permitted.

Work on the science of controlled missiles was being carried out in every area visited in Allied occupied territory, from the border of Denmark to Switzerland and from the coast of France to the Russian zone of occupation. It is a known fact that some work was being done in Denmark, Norway; and Poland, and it is estimated that 50% of the total German effort in this field was in what is now Russian-occupied territory. The results of the enemy's guided missile work are self-evident on the targets in England, Belgium and Holland.

Guided Missile Program

The German guided missile program during the last stages of the war provided for development of every conceivable basic type, one classification of which follows:

(a) Surface launched to air targets.
(b) Air launched to air targets.
(c) Air launched to surface targets.
(d) Surface launched to surface targets.
(e) Underwater launched to underwater targets.
(f) Underwater launched to surface targets.
(g) Underwater launched to air targets.

Research Projects

Although rocket and jet propulsion applications were being made in the conventional airplane and weapon fields, the vast majority of research, development, and subsequent manufacture of rocket motors was predicated on the requirements of the guided missile program. The most extensive and important rocket and jet work was concentrated in the following activities:

(a) Walter Werke (Kiel) liquid rockets.
(b) Rheinmetall-Borsig (Berlin) liquid and solid rockets.
(c) Bavarian Motor Werke (Munich) liquid rockets and turbo jets.
(d) Wilhelm Schmidding (Bodenback) solid rockets.
(e) Dr. Konrad—Liquid rockets.
(f) Dr. Alexander Lippisch—Ramjet.
(g) Argus Werke—Resojet.
(h) Dr. Schmidt—Improved resojet.
(i) Peenemunde—Liquid rocket.
(j) Dynamite, A. G. — Solid propellants.

Propellant Types

Rocket powerplants developed in Germany are of two types, one type manufactured by Walter Werke using hydrogen peroxide and a catalyst, and a second type developed by the Peenemunde Group, BMW, and Rheinmetall-Borsig using nitric acid and amines as propellants. Walter used a spray type injector whereas the nitric acid—amine combination utilized the conventional multiple hole impinging type injector. Since the German Navy consumed large quantities of hydrogen peroxide, in the last stages of the war nitric acid was being used almost 100 per cent. as the oxidizer. Also in favor of nitric acid was the storage problem since missiles using acid could be filled at the factory whereas peroxide units had to be filled just before launching.

General Developments

In general it can be said that German rocket design and engineering is no further advanced than in the United States but production and application is far ahead.

It is estimated that one-third of the energy directed to aerodynamic research in Germany was devoted to the problems of guided missiles. The research laboratories at Braunschweig, Goettingen, Darmstadt, Ainring, etc., were involved in major projects and the above establishments have capacities exceeding anything previously dreamed of in America. There exists in Germany numerous wind tunnels with a Mach number of 4, i.e., four times the speed of sound. One tunnel with a Mach number of 10 was being considered. Some degree of guided missiles research was being carried out in all of the above tunnels.

It has been gratifying to find a few isolated items relating to the field of guided missiles in which the German product was inferior to similar accomplishments in America. However, this is subject to being misconstrued if used to magnify our virtues or exonerate our failures by so-called experts who have "surveyed the field" in a few weeks, returned to America and announced they are disappointed to find the Germans have nothing to offer. Such a statement is evidence of the individual's refusal to accept the obvious fact, inexcusable if made in innocent though stupid sincerity, and criminal if made for ulterior motives.

Conclusions

From observation of the enemy's work, it is concluded that:

(a) If given a relatively short period of time, Germany would have succeeded in bring into the war an effective counter measure against aerial bombers. She would have produced infinitely superior assault weapons through intensive exploitation of the science of guided missiles;

(b) From the standpoint of future warfare, the work of the Peenemunde and associated groups without question ranked among the most important being done in Germany on any subject. Although the apparent results of this organization have been extensively covered by investigators, determination of the groups' ultimate goal remains an assumption based on the trend of their developments. Undoubtedly they expected to produce weapons from the A series with which they could accurately hit any area on the face of the earth. It is equally obvious that with the V2 they were not only working out in advance the aerodynamic and control problems of such weapons, but that in the present weapon they had a proven vehicle ready to receive whatever radically new explosive and propulsive substance they expected to become available. It is inconceivable that the V2 was considered by the German scientists to be an end in itself, nor that with all its complexities, it was developed at the cost of billions of dollars and manufactured in great quantity with highest priority merely to deposit 750 kilograms of explosive on British territory.

If in any country the development of the weapons with which to fight a future war is, as it has been in the past, dependent only on the impetus of the war for support, that country when attacked will not survive the first operation.

ERRATUM

The term "Wadrc" is the correct designation for the aircraft design described in the article "The Flying-Submersible" in No. 63 issue of the JOURNAL. Wadrc at one time was the abbreviated title of the Wolcott Aeronautical Design and Research Company. The new title contains the same identical abbreviated words with the exception that Aeronautical is changed to Astronautical. Active research of the firm is at present concerned with the Flying-Submersible, with future research stressing astronautical designs.

Random Thoughts On Atomic Power

Possibilities Of Nuclear Energy For Rockets

By WILLIAM D. MONROE

Since the explosion of the first atomic bomb over Japan, the scientfic world has been acutely aware that an abundance of nuclear energy fuel is almost within its grasp. Hand in hand with this realization goes intense speculation as how to best apply this new power to prime movers. Here however, will be considered the possibility of its application to rocket engines only.

Unless the writer's knowledge and recent literature is grossly in error, there are two so-called atomic fuels available at present, U-235 and U-239. Just now, plutonium 239, converted from uranium, is favored because of the relative value as compared to pure uranium.

The first problem to be solved before atomic energy may be feasibly applied to anything other than wholesale destruction, is establishing an adequate control over the rate of energy release, b.t.u. per second. This is necessary so that a reasonable rate of energy released per unit of time may be obtained, instead of a violent explosion. In the late 1930's it was suggested that this control might be had by alloying a dampner of ordinary uranium with U-235. (Plutonium was unknown at that time). It was reasoned that the rate of energy release would be dependent on the ratio of uranium to U-235 . It is possible that such control may be established for both U-235 and plutonium.

Rocket Application

At first a method of applying this energy to a rocket engine is far from obvious, as the energy takes the form of intense heat. Closer consideration and an analogy will point the way. The energy in coal is used to drive a steam engine. The coal is first burned to release its heat energy. This heat energy is applied to a working fluid, water, to form steam which is in turn used to drive the engine. Immediately it becomes clear that an atomic powered engine must have a working fluid in order to function. It has been suggested that a block of U-235, alloyed with the proper amount of plain uranium, could be submerged in water to generate steam, to drive any prime mover.

Atomic Heat Uses

This could be used in rocket engines by simply applying the heat energy from uranium fuels to some working fluid and allow the working fluid to form the jet. There are three obvious uses for the heat obtained from the atomic fuels:

1. To heat water to form high velocity steam jets.

2. To disassociate water into hydrogen and oxygen. The hydrogen and oxygen being later burned to form the jet.

3. To heat mercury to form high velocity mercury vapor jets.

In the table the resulting thrusts, jet velocities, maximum velocities and M0/M1 ratios have been tabulated so that the results may be conveniently compared to the performance figures of the German V2 rocket. The figures for the V2 were arrived at by using the data presented for it in Life Magazine some time ago.

In all cases the following assumptions were made in order to have a basis for comparison:

1. Air resistance was completely ignored.

2. The acceleration due to gravity, g, was assumed to be 32.2 ft. per sec.

Table I

Fuel	Al & O.	Atomic	Atomic	Atomic
Working fluid	——	H_2O (Steam)	H_2O (H_2 & O_2)	Hg
M0/M1	4	3.98	3.98	40
Discharge lb./sec.	260	260	260	Not Cal.
Vel. exhaust ft./sec.	6400	4870	7800	Not. Cal.*
Thrust lbs.	48,000	41,800	63,000	Not Cal.
Maximum vel. ft./sec.	7320	6140	9240	Not Cal.
Alt. miles	213	160	310	Not Cal.

*Using mercury vapor at 900 lbs. per sq. in. and 5000°F exhausting it to 15 lbs. per sq. in. an exhaust velocity of only a little more than 2000 ft. per sec. was obtained

per sec. regardless of the altitude obtained by the vehicles.

3. A dead weight load of three tons was assumed in all cases. Three tons being the dead weight carried by the V2.

4. The same cubic foot liquid capacity was used throughout. The specific gravity of the various fluids accounting for the various M0/M1 ratios.

5. For all but the mercury, a discharge rate of 260 lbs. per sec. was assumed.

Steam Assumptions

It is interesting to note that, for the water-steam combination, the size of the nozzle was found to be so great as to be prohibitive. Conditions assumed were 3000 lbs. per sq. in. steam at 1000°F. being exhausted to 10 lbs. to the square inch.

The exhaust velocity for the water combination, hydrogen-oxygen, was arrived at by assuming that the same ratio of actual to theoretical jet velocities could be obtained by the Germans with their alcohol-liquid oxygen combination.

Mercury Considerations

Although mercury vapors have been used for years to drive mercury turbines in a binary steam system, very little has yet been published on the thermodynamic qualities of its superheated vapors. A study of the weights involved revealed in fact, that to be practical at all, mercury vapors must develop exhaust velocities of around 10,000 ft. per sec. A purely theoretical consideration of the problems brought out, is the fact that to have reasonable exhaust velocities, the almost impossible temperatures of 5000°F. and above would be needed.

BOOK REVIEW

U. S. Rocket Ordnance, Development and Use in World War II. Released by the Joint Board on Scientific Information Policy for: Office of Scientific Research and Development, War Department, Navy Department, March 30, 1946; 57 pages.

This publication describes the great variety of rocket weapons developed by the United States and their spectacular use in World War II. Following a foreword on rockets at war, the chapters review the history of rockets, rocket fundamentals, organization of rocket laboratories, rocket versus submarine, rocket armament for aircraft, rockets for amphibious warfare, bazooka versus tank, rockets for ground warfare and specialized uses of rockets.

Society Publishes Goddard Reports

The Society has announced the publication of the collected works of Dr. Robert H. Goddard, together with additional material, in a single book under the general title of "Rockets, by Dr. Robert H. Goddard." The first edition is to be limited to 2,000 copies and be available about May 1, 1946.

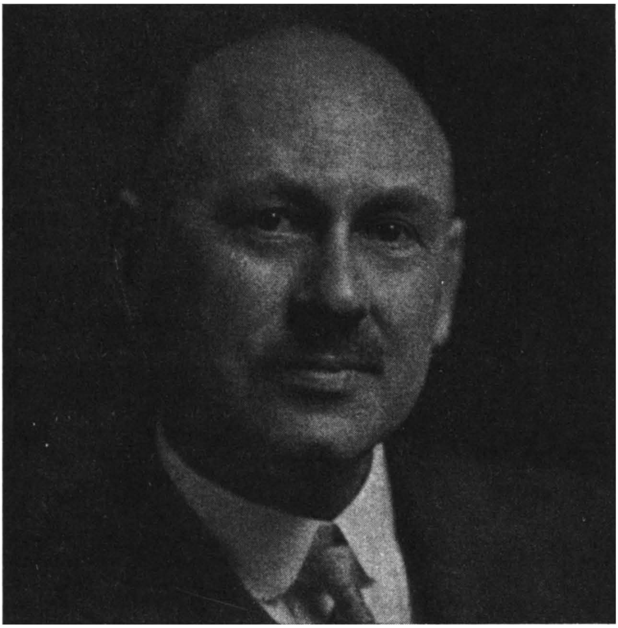
The book contains the two famous reports by Dr. Goddard - now out of print - which provided the scientific foundation for all modern rocketry and jet propulsion:

"A Method of Reaching Extreme Altitudes"

"Liquid-propellant Rocket Development"

with a new foreword by Dr. Goddard, written for this book shortly before his death and never before published.

Republication of the works of the foremost authority on rockets and jet propulsion is by special arrangement with the Smithsonian Institute and the estate of Dr. Goddard.



Dr. Robert H. Goddard, pioneer of modern rocketry and jet propulsion. October 5, 1882 — August 10, 1945.

Modern Pioneer

The untimely death of Dr. Goddard* on August 10, 1945, ended one of the most important careers in the history of science, and cut short the work of the world pioneer in rocketry and jet propulsion. At his death, both of Dr. Goddard's famous technical reports, originally published by the Smithsonian Institute in 1919 and 1936, were out of print. In "Rockets" they are now made available again to engineers, scientists, students and general readers.

---

*Dr. Robert H. Goddard, Journal of the American Rocket Society,No. 63, September 1945.

Is Rocket Contact With The Moon Possible?

A Resume' Of The Spatial Rocket Problem

By RAY A. HEFFERLIN

The recent establishment of radar contact with the moon has loosed a storm of speculation on lunar exploration that is the immediate sequel to any advance in the field. But speculation must give over to down-to-earth planning if anything worth while is to be accomplished. In the following discourse some of the problems and solutions of a moon rocket will be presented.

Fuel Problem

The present inadequacy of the fuel makes a rocket at the present time nigh impossible. In order to have the mass-ratio of 30 to 1, which represents an upper limit because of structural difficulties of even an auxiliary rocket, an exhaust velocity of about 6000 yd. per sec. is required. The best fuel available now only has a velocity of about 2500 yds. per sec.* Atomic power may eventually solve this problem.

Many calculations on rockets are based on a one-way trip to the moon. But generally it is most important for the ship to return, if only to learn just how metals are affected by the radiations of space. Therefore, it would be well to plan on using what fuel the rocket can carry internally for the return trip. Not very much will be required, as the moon's mass is about 1/81 that of the earth, and its gravity correspondingly lessened. Most of the fuel for the outgoing trip would be supplied by the referred to auxiliary.

Steering Apparatus

Another item is adequate steering arrangements. Turning, taking off from the surface of the moon, and deceleration would be functions of such an apparatus. Normally, the jet tubes would be at rest as shown in Fig. 1. In taking off or in ascending the side jets would be pointed in a downward direction to lift the nose of the rocket to the proper elevation. In acceleration or deceleration all four tubes could be used.

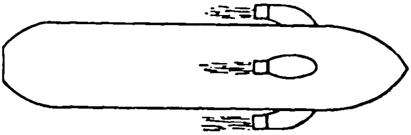


Fig. 1. Rocket with four movable jets.

Structural Shape

The operator would be confined in a ten-foot sphere in the forepart of the ship. The sphere was chosen first because of it being superior to other shapes of construction for strength and maintenance of pressure, and second because it would afford the convenience of allowing the operator to remain upright. The cabin would rotate about an axis perpendicular to the gravity force through an arc of 270 degrees. A cabin without this refinement would necessitate the operator being flattened against the aft of the cabin while under the earth's gravity and the forepart while descending upon the moon. The atmosphere would be of a helium-oxygen mixture which would not cause the bends if a part of its volume was suddenly lost. Various devices would detect any small variations of pressure. The difficulty of getting various circuits through the necessarily air-tight walls of a ball which revolves through 3/4 of a circle is obvious. One possible answer would be by having tracks on the outside of the compartment perpendicular to the axis rotation on which small shoes would allow the current to pass. Possibly some sort of

---

*Ley, Willy, "Rocket to the Moon?" Mechanix Illustrated, September 1945.

radio control for this purpose could be devised.

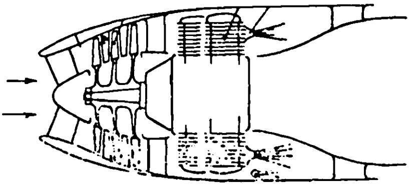
Construction

The entire rocket would of course be composed of the lightest possible metal that would fulfill the structural necessities. The windows would be made in such a fashion as to sift out all injurious radiations. The rest of the ship would consist of fuel storage and combustion chambers plus controls and motors for auxiliary rocket tubes. Air-tight pressure would be maintained by wound wire, steel plating and supports all filled in with a light but non-porus substance like that used in coils of electric motors. The outer surface should be as smooth as possible and highly polished to reflect radiations. The portion of the ship surrounding the cabin would be glassed in all the way around in order to provide visibility when the cabin is in any position.

Meteorites

The above would provide two surface protection against small meteorites. Large meteorites would of course not be even slowed down by these walls. The huge numbers of meteorites hitting the earth seem forbidding, but the earth is so much larger than a rocket that the chance of it being hit is very small.

Thus it appears that the development of a rocket will have to wait on a favorable fuel and sufficient capital, but that does not stop one from making tentative plans and whetting the imagination.



No. 2,396,911, "Reaction Propelling Device for Aircraft"; Rene Anxionnaz, Paris, and Roger Imbert, Mantes, France.

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. 2,394,513, "Flow Controlled Helicopter"; Jean Olivier de Chappedelaine, Reading, Pa.

No. 2,394,852, "Liquid Feeding Apparatus"; Robert H. Goddard, Roswell, New Mexico.

No. 2,395,113, "Mechanism for Feeding Combustion Liquids to Rocket Apparatus"; Robert H. Goddard, Roswell, New Mexico.

No. 2,395,114, "Rotating Combustion Chamber for Rocket Apparatus"; Robert H. Goddard, Roswell, New Mexico.

No. 2,395,403, "Rotatable Combustion Apparatus for Aircraft"; Robert H. Goddard, Roswell, New Mexico.

No. 2,395,404, "Aerial Propulsion Apparatus"; Robert H. Goddard, Roswell, New Mexico.

No. 2,395,405, "Landing Apparatus for Rocket Craft"; Robert H. Goddard, Roswell, New Mexico.

No. 2,395,406, "Combustion Apparatus"; Robert H. Goddard, Roswell, New Mexico.

No. 2,395,809, "Rocket Directing Apparatus"; Robert H. Goddard, Roswell, New Mexico.

No. 2,395,919, "Auxiliary Power Plant for Airplanes"; Albert T. Sundell, Chicago, Ill.

No. 2,396,130, "Air Jet Propelled Helicopter"; Anthony Sbrilli, Atlanta, Ga.

No. 2,396,566, "Rocket Apparatus"; Robert H. Goddard, Roswell, New Mexico.

No. 2,396,567, "Combustion Apparatus"; Robert H. Goddard, Roswell, New Mexico.

No. 2,397,114, "Rocket Construction"; Ralph Anzalone, Oceanside, N. Y.

No. 2,397,357, "Reaction Turbine Propeller"; John J. Kundig, Hasbrouck Heights, N. J.

—C. G.