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FILE No. XXVIII-53

WALTER WERKE, KIEL

COMBINED INTELLIGENCE OBJECTIVES
SUB-COMMITTEE

WALTER - WERKE, KIEL

Reported by:

Capt. C.L. BARHAM, M.O.S.
F/Lt. R. SIMARD, M.A.P.

CIOS Target No. 5/3 & 5/69
Jet Propulsion

COMBINED INTELLIGENCE OBJECTIVES SUB-COMMITTEE
G-2 Division, SHAEF (Rear) APO 413

C.I.O.S. Report

[illegible] [illegible] at Walter-Werke, Kiel

Object of Visit

This report covers the results of the investigation carried out at Walter-werke, Kiel, by

Capt. C.L. Barham (P.D.E., Ministry of Supply)
and F/Lt. R. Simard, R.C.A.F. (Power Jets, Ltd., M.A.P).

These two officers were primarily concerned with investigating the work that had been done on propulsive ducts, but a number of other products of interest were also examined.

The party left London on 5.6.45 arriving in Kiel the next day. Capt. Barham left Kiel on 16.6.45, reaching London on 18.6.45. F/Lt. Simard left Kiel on 18.6.45, arriving in London on 19.6.45.

Apparatus and Equipment Available

A number of sets of propulsive duct components had been made up for static tests on a small scale, and several of these were found in the firm's testing plant at Wik, Kiel. Permission was sought from Cdr. Aylen, R.N., the Admiralty Engineer Overseer at Walter-werke, to send back to England four model ducts and a number of burner components from different stages of the development. Cdr. Aylen has asked Admiralty sanction, which is still awaited.

Most of the components for a full scale model had been constructed at the firm's main engineering plant, at Beerberg, in Silesia, and these had been brought back to Lübeck, en route for Kiel. On investigation, however, it appeared that the burner components had been sunk in the sea, and only the diffuser remains.

The Wik testing plant is essentially intact, though some local damage to buildings had been sustained largely from blast. The electrical supply from the power station had been cut in the heavy raid of last April.

Introduction

The firm started on a research programme of work to test the principle of the propulsive duct (Luftstrahl Antrieb) in 1936. The work continued on a research basis until a few months ago, when the scheme began to look attractice as a practical method of aircraft propulsion. Construction of a full scale model for aircraft flight trials was in hand.

A description of the testing plant used is given below, followed by a summarised history of the development of the propulsive duct motor, and a description of the full scale model in course of preparation for wind tunnel tests and flight trials. Various methods are then discussed that were examined for surmounting the difficulty that the athodyd alone cannot be used for take off.

Most of the information given was obtained from Herr Dipl-Ing. Lensch, director of research at Walter-werke, but some was given by Dr. Schmidt, in charge of development. Both these men appeared quite open and willing to talk.

More precise details are available in a number of reports. Before the surrender, all reports and drawings were destroyed, but as a preliminary to this they were all microfilmed. The microfilms are available, and a request has been made of Cdr. Aylen for reproduction of the reports of interest. Some of these have already been obtained; the remainder are awaited.

Testing Plant

For testing purposes a compressor plant was constructed a short distance from the Kiel power station. The power used was 800 Kw. and the plant could deliver 7 Kgs. of air per second at 6 at. in continuous running at speeds up to 340 m/s., i.e. up to the speed of sound. The normal working pressure was 1 at.

This plant was used for testing the internal flow through the whole duct, and could take models up to 175 mm. entry diameter; the entry orifice used normally was 112 mm. The compressor used was designed by Walter himself and used originally for gas turbine work. There seems to be nothing particularly novel in its design or construction.

Pressure and temperature could be measured at a number of points along the duct. It was also possible to measure the lateral flow of air into or out of the duct in the event of a sub-pressure of excess pressure at the outlet.

L-motor (Lorin, propulsive duct)

A diagrammatic sketch based on the latest design is given in figure 1.

The original design for the 1936 tests had a combustion chamber of large diameter so that the gas velocity at the combustion chamber entry would be low and therefore no difficulty should be experienced with ignition. The diffusor entry was 112 mm. in diameter, and after a short parallel length it expanded in two conical sections of total angles 4° and 8° respectively, to the diameter of the combustion chamber, 500 mm. The exit diameter corresponding to a combustion temperature of 1000°C. was 175 mm. The length of the combustion chamber was 1200 mm.

In the early experiments propane was used as the fuel on account of the ease with which it vaporizes. A change was later made to petrol, and some experiments were also carried out with heavy diesel oil. The fuel was sprayed downstream from a ring containing a large number of orifices. The ring was backed by two cylindrical shields.

Tests were carried out on this model over a range of combustion temperatures and air velocities. It was found that a compression efficiency of 86 per cent. was obtained and an expansion efficiency of 92 per cent. The velocity of the air entrained over the surface of the duct was sufficient for adequate cooling. The tube temperature for a combustion temperature of 1000°C. was of the order of 600°C. The specific fuel consumption varied from 9 gr./Kg/sec. down to 1.2 gr./Kg/sec. according to the temperature and velocity. For a speed of 280 m/s and temperature of 1000°C., the normal test conditions, the theoretical specific fuel consumption assuming no losses was 1.07. The value obtained in the tests was 1.22 gr./Kg/sec.

With the large diameter combustion chamber, the drag would be greater than the thrust but it was considered that the tests had established the principle. Subsequent work was directed towards reducing the dimensions of the equipment with a view to determining the optimum size.

The diameter of the combustion chamber was progressively reduced to 250 mm., the entry and exit orifices remaining unaltered. At this stage the air velocity at the entry to the combustion chamber was about 100 m/s for air speeds of the order of 300 m/s. This high speed led to combustion difficulties. One serious difficulty with speeds of the order of 80-100 m/s was in getting adequate mixing. To overcome this trouble, jets were added which ejected sideways across the air stream, and a second ring of jets was added round the wall. The flame from the original ring of burners was directed downstream onto a steel ring which diverted it sideways to ignite the mixture of fuel and air, which by that stage was well mixed. This arrangement led to combustion across the whole area of the combustion chamber.

Ignition was satisfactory at external air speeds up to 185 m/s with a single spark (using propane). At higher speeds, if the flame was blown out, burning would not recommence. To obtain a flame which would not blow out, an arrangement was devised consisting of a piece of porous material on to which petrol was injected. A rich mixture was formed behind the porous material and this was ignited by a sparking plug to give a steady flame. This gave satisfactory results up to the maximum speed.

At this stage models were tested in the wind tunnel of the Luftfahrtforschungsanstalt at Brunswick for determination of the net thrust. An outer skin was fitted over the diffuser to give a good aerodynamic shape, and it was found that the drag was rather less than half the thrust. At 280 m/s airspeed the thrust recorded on the static test bed was 105 Kg. The corresponding net thrust in the wind tunnel was 58-60 Kg. The total external drag, calculated as the difference between these two thrusts, was about 25 per cent. higher than the calculated skin friction on the outside surface.

A simple parallel section was not the optimum for the combustion chamber, from the point of view of internal flow. To maintain a constant pressure, which gives optimum conditions, requires an expanding cross-section to allow for the continuation of combustion. This form was found to fit in with aerodynamic considerations on the external flow. Dr. Zobel of Brunswick, working with Busemann on aircraft forms, discovered that at speeds approaching the sonic region the best drag shape is an inverted drop with the maximum cross-section in the region of 1/3 of the length from the tail. It was stated that at speeds of 260-280 m/s this shape had only about half the drag of a drop shape with maximum cross-section at 1/3 of the length from the nose. The duct shape was therefore altered so that the diameter was greatest towards the tail. The increase in net thrust was some 5/6 per cent.

This last modification had led to some reduction in the length of the combustion chamber, as combustion was completed earlier through the maintenance of constant pressure. To obtain a further reduction in length experiments were initiated with injection of fuel forward, so that mixing should start in the diffuser. To facilitate mixing, the direction of the jet was skew to the duct to set up turbulence, and the fuel was ignited behind these baffles. Tests with different burner systems had not been finally completed but it was hoped to reduce the length of the combustion chamber to 700 mm.

It was found that the diffuser length could be reduced to 350-400 mm, without serious loss of compression. A test with a zero length diffuser, i.e. a plain orifice, gave a 20 per cent. loss.

Tests were carried out with various forms of tail in an attempt to reduce drag, e.g. by sucking away the boundary layer. The results were of doubtful value, as the differences recorded were only of the same order of magnitude as the error of measurement.

Full scale propulsive duct model for aircraft flight trials

A full size propulsive duct suitable as a drive for the Ju 263 aircraft was in course of manufacture. It was proposed to mount two ducts, one under each wing fairly close to the fuselage in order to minimise the yawing moment caused by the failure of one of the ducts.

The normal jet drive would be used for take-off and climb and the ducts would take over when a suitable speed was reached. Unfortunately, only the diffuser is available; the burners and baffles had been manufactured but were sunk in the sea. Detailed drawings are not available.

The combustion chamber diameter was to be 840 mm., and the total length 2500 mm., the diffuser being about 900-1000 mm. The diffuser and fairing were of light alloy, and the combustion chamber of steel 1 mm. thick.

Fuel would be injected some way down the diffuser from a streamlined ring containing 9 plain holes directed towards the axis and 9 away from it. These jets were arranged in three groups, which could be brought in by the control device one after the other. At the entrance to the combustion chamber was a baffle system comprising 4-5 concentric rings fitted on two perpendicular cross pieces. Symmetrically placed on this arrangement were four jets fed by T-stoff and C-stoff from the fuel used for the starting rocket drive; these jets were used for ignition of the fuel-air mixture, and it was claimed that the flame would remain alight under the conditions of use envisaged.

Each duct was designed to give a thrust of 450 Kg at sea-level or 200 Kg at 10 kilometers height, for a speed of 220 m/s. To maintain the correct working temperature (1000-1200°C.) it was necessary to control the rate of fuel feed according to speed and height. A valve generally similar to that used on the Hs 117 was envisaged. (A report on this is available). Another method that had been suggested was a control operated by the temperature itself, but this was shelved on account of the difficulty of obtaining a material which would stand up to the temperature in the combustion chamber.

Fuel was supplied by means of a pump developing 4 H.P. and working at 10 at. pressure. The T-stoff and C-stoff for ignition were supplied by an air bottle feed, and could be cut out when the duct was functioning properly. The duct would work from 80 m/s upwards.

This design was mainly a scaled-up version of the small models which had been tested satisfactorily; the combustion chamber length, of course, does not increase in proportion to the diameter. Before proceeding to actual flight trials it was proposed to test the full size model in the BMW wind tunnel at Munich.

RL-motor (Rocket-Lorin)

The simple propulsive duct suffers from the disadvantage that at zero airspeed the thrust is zero; an auxiliary motor must therefore be used for take off and acceleration to a suitable speed. As an alternative to using a separate motor, various combinations of duct with a rocketor turbine to induce the necessary flow of air have been tried.

This section deals with the case of a rocket venting into the duct inlet. A diagrammatic sketch is given in figure 2.

Two types of T-stoff rocket motors were considered, those called hot or cold according as combustion takes place or not. In the cold type T-stoff (H_2O_2) is decomposed over a catalyst to produce the usual mixture of 62 per cent. steam and 38 per cent. oxygen at a constant temperature of 550°C. The hot type goes one step further, by burning a fuel, usually C-stoff ($N_2H_4.H_2O$ / CH_3OH), in the mixture of steam and oxygen from the decomposition of T-stoff. Much higher temperatures are obtained, which can be varied by controlling the amount of C-stoff used. The specific fuel consumption of the cold type is constant at 9.5-10.0 gr/Kg/sec.

In the RL-motor research, most of the work was done with a rocket of the cold type.

The rocket discharge is directed straight into the inlet of the propulsive duct. Later tests were carried out in which the gases were led into a hollow chamber surrounding the duct entry, from which they are directed through jets along the inside wall of the mixing chamber. The stream of gases draws in a large quantity of outside air thus providing a large air mass and the necessary compression at entry, also providing an excess of oxygen to burn the petrol supply to the propulsive duct.

The first models were provided with a large bell-shaped entry to the propulsive duct which even when streamlined with an outside fairing gave a rather large drag. This defect was remedied by decreasing the diameter of the bell-shaped opening until it was found that as long as the entry edge was rounded and with a diameter greater than 20 mm., no appreciable resistance loss to the air entry was encountered.

In order to allow time for the energy of the rocket exhaust to be transferred to the incoming cold air, a straight tube 700 mm. long had to be provided between the rocket exhaust and the beginning of the propulsive duct diffuser. This length was found sufficient to ensure adequate mixing before entry into the duct proper. It was determined by velocity head traverses; the minimum length which shows a velocity profile comparable with the theoretical profile of streamline flow in a pipe is the optimum length required for mixing.

The output of the rocket is important as there is a maximum amount of energy which gives maximum thrust. In other words the velocity and mass of rocket gases must be such that the suitable amount of air is drawn in.

Experiments were made with rocket venturias ranging in throat size from 3 to 15 mm; the 10 mm. size was finally adopted because it gave the lowest specific fuel consumption at a ratio of 1 part of

T-stoff to 6-7 parts of air. The T-stoff pressure was 30 at. which produced a steam and oxygen stream with a velocity of 1000 m/s. Under these conditions the air velocity was about 50 m/s at the inlet.

The simple propulsive duct develops a gross thrust of about 100 Kg at 280 m/s. The net thrust (gross thrust - drag) of the RL-motor in the wind tunnel ran from 100 to 120 Kg at air velocities of 0 to 240 m/s, the net thrust of the RL-motor being thus consistently greater than the gross thrust of the L-motor alone.

The maximum thrust of the RL-motor (120 Kg) was obtained at a ratio of T-stoff gas to air intake of 1 to 4. However, the minimum specific fuel consumption occurred at a ratio of T-stoff to air to 1 to 6-7. The thrust is then only 80 Kg, but the specific fuel consumption drops from 9.5 to about 4-5 gr/Kg/sec., with about equal proportions of T-stoff and petrol.

These thrust and fuel consumption values take into account the relative quantities of T-stoff and normal petrol fuel for the propulsive duct which are fixed by the necessity for obtaining efficient compression and keeping the temperature at 1000°C., the most efficient temperature for the constant ratio of inlet to outlet areas. With a large rocket allowing no extra air entry, the T-stoff consumption is 9.5 gr/Kg/sec. for the rocket alone, but due to large losses in the now inactive duct, the thrust is reduced and the overall specific fuel consumption rises to about 25 gr/Kg/sec. With a small rocket, insufficient compression causes a lower thrust output and the specific fuel consumption can become indefinitely large as the T-stoff consumption approaches zero.

LR-motor (Lorin-Rocket)

This combination of propulsive duct and rocket (shown diagrammatically in figure 3) was tried but did not prove as successful as the RL combination. The rocket being in the outlet of the propulsive duct sucks air through the inlet and the rocket body is in the stream of hot gases, requiring special cooling devices to protect it. The structural difficulties were also quite great.

Results obtained showed that the total thrust produced was equal to the sum of the thrusts of each component and that these individual thrusts varied with fuel consumption independently of each other. The only advantage of this type of motor, besides the increased thrust from two components instead of one, was the slight reduction in skin friction and turbulence at the outlet due to the section action of the rocket discharge gases.

TLR-motor (Turbine-Luft-Rocket)

In this system the air is drawn in and compressed by means of a compressor which is powered by a straight T-stoff turbine. This combination gives a better compression ratio and thus greater efficiency, while the combustion gases, to which is added the steam and oxygen discharge of the turbine, are allowed to give up all their energy in the form of thrust without having to drive a turbine to run the compressor. Its main advantage is the use of two separate fuels. It generally approximates so closely to the normal gas turbine engine that its development was abandoned in favour of the Jumo 004.

Einstoff RL-motor (Single fuel Rocket-Lorin)

This scheme is shown diagrammatically in figure 4: it is a development of the RL-motor described earlier, but in this case the rocket compression and air suction are provided not by T-stoff but by a stream of vaporized and superheated fuel. The heating, vaporizing and superheating of the fuel is done by circulating it through a coil wound around the combustion chamber from which it is led to the discharge nozzle at the inlet of the propulsive duct. Mixing of the fuel vapour with the entrained air takes place as before in a length of tube, after which spontaneous ignition takes place. This feature of course eliminates the necessity for burners but requires the presence of a hot surface at the entrance to the combustion chamber to localize and stabilize the combustion.

Experiments were made with a fuel pressure of 25 at. and a nozzle temperature ranging from 500° to 700°C. Since the venturi used was the one giving the minimum specific fuel consumption at a ratio of 1 to 7 fuel to air, petrol was discarded and methyl alcohol used because it requires a 1 to 7 ratio of fuel to air for stoichiometric combustion. It also had the advantage of vaporizing cleanly without residue or cracking. Starting was done by means of an auxiliary fuel vaporizer until the combustion chamber was hot enough to bring the fuel vapours to the required temperature. The main trouble of this system is the control of the temperature to get spontaneous ignition neither too early nor too late; also every decrease in combustion chamber temperature due to faulty combustion immediately decreases the temperature of the fuel vapours, thus aggravating the situation still further.

Intermittent Jet Action

Air Drive

The continuous propulsive duct necessarily works at a low ratio of pressures and in consequence has a low thermal efficiency. The thermal efficiency can be increased if the pressure ratio is increased. The intermittent jet is an attempt to increase the pressure ratio.

Its principle is simple: fuel is injected into a pipe open at one end and closed by a valve at the other. The fuel-air mixture is exploded and the gases vent through the open end of the tube. When the pressure on the inner side of the valve becomes a sub-pressure, the valve opens, air flows in, and the cycle is repeated.

Walter was working on this principle, which, in addition to providing the method of propulsion for the flying bomb, V1, also had applications as a turbine drive. A valve was designed consisting of two hemispheres fitted with ports rotating on co-axial spindles in opposite directions to provide a guide action. (A frequency of about 50 cycles per second is required). One valve was made up and tested satisfactorily, but work was then stopped on account of the success of the V1 mechanism. No work has now been done for 2½-3 years, and the valve components are no longer available as the heat-resisting metal used was needed for other purposes on account of shortage of such materials.

Although the maximum pressure ratio with this system is 8-10, the average over the whole cycle is only about 2. In an attempt to increase the efficiency by increasing the mean pressure, a scheme was devised consisting of two interconnecting tubes with valves at each end. The theory was that when the compressed gases from one explosion reached the far end of the tube, more fuel would be injected, and a new explosion would increase the consumption. This somewhat complicated scheme was never put into practice.

Considered as a method of propulsion, the thrust of the intermittent jet system increases with the air speed, but since its shape necessarily corresponds to a high drag, the net thrust begins to drop rapidly above about 100 m/s. At speeds in the region of 200 m/s, the net thrust has dropped to the level of that of a continuous jet with the same fuel consumption, and at higher speeds the latter has the advantage. At about 220 m/s the net thrust of the intermittent jet unit drops to zero.

Underwater drive

It was proposed to use an intermittent rocket action together with an augmentor device for underwater propulsion. This is not strictly akin to the intermittent propulsive duct described above as an air drive.

Some work was done on a T-stoff rocket torpedo with an augmentor fitted behind. It was stated that an augmentation of up to 60 per cent. had been obtained with a plain steam jet, but only some 5 per cent. was obtained in these trials. It was pointed out that only ad hoc tests had been possible as a quick answer was required by the Kriegs-marine. Following these inconclusive results, the priority was dropped.

About Christmas 1944, work was started on an intermittent jet with augmentor action. This too gave negative results, largely because of the absence of a satisfactory intermittent motor. Work on the main project therefore stopped but development of the intermittent rocket motor continued. This was finally developed into a minesweeping device and reached the stage where full scale trials were about to take place. With completion of this development, the augmentor trials could have been re-started using a higher frequency version of the motor.

The mine-sweeping device depends on the explosive reaction of T-stoff with B-stoff to produce sound waves under water. The two fuels are fed from their respective tanks into a short cylindrical explosion chamber with an inside diameter of about 6 inches, by means of plungers actuated by a spring-loaded lever which is released by a cam. The spring load causes a rapid movement of the plungers and the fuels are injected quickly along a rangent of the cylindrical chamber so that, due to centrifugal force, the two fuels form a liquid layer on the inside surface. The explosion delay is just long enough to allow complete feed of both fuels after which their respective non-return valves automatically close. The sharp explosion which is produced at the rate of one every second is claimed to be effective in exploding acoustic mines at a range of 1500 meters. The explosion gases are allowed to escape through an orifice and their escape is facilitated by the scavenging action of compressed air which is obtained from an air piston actuated by the upward motion of the spring lever as the spring is compressed by the cam in readiness for the next cycle. The source of power for the cam is a small electric motor. The entire driving mechanism is located on board the mine-sweeping vessel and the explosion chamber was to be fixed on the bow of the ship.

Thrust Augmentors

As stated in the section on intermittent jet action above, some work was done on thrust augmentation under water, with negative results. Thrust augmentation in air was also investigated. It was found that with the optimum shape of augmentor and the optimum size relative to the rocket used, the rocket thrust could be increased by up to 120 per cent. with a stationary motor. It was stated that as the forward air speed of the motor increases up to the speed of sound, the thrust drops to a minimum below that obtained without an augmentor and then rises again. No reason was given for this behaviour, but reference was made to a paper by Busemann written in 1939-40. The exact title and reference could not be found.

No components of the augmentor device are available. A report on the investigation may exist, but was not found.

Ballistics Investigations

ssisted Shell

rr Lensch stated that a proposal was at one time put forward for T-stoff rocket to increase the range of a gun shell. The pro- ever got beyond the stage of calculations, largely on account strength and weight of the components required to withstand the celerations.

lculations were carried out to determine the optimum part of the ory for rocket action; according to Lensch, the results showed ximum range was obtained when the rocket fired in the upper, low region of the atmosphere. A report was said to be available, not found.

ingolene in guns

e object of this development was primarily to give a constant curve along the gun barrel. By feeding ingolene continuously e chamber and decomposing it over a catalyst instead of using osive charge, it should be possible to maintain a relatively nt pressure. Satisfactory results were achieved with a 15 cm. , giving a range of 2000 m. This weapon, called the P-werfer, atively silent and invisible at night, though by day a cloud n could be observed.

en consideration was given to applying the principle to a long un, which was the primary object of the investigation, it was hat the uniformity of pressure obtainable was limited by the gas transmission. The difficulty could be overcome by feeding progressively at a number of points along the barrel. The same le could of course be adopted with an explosive charge, but an ge of using ingolene is that a single combustion chamber could be e gas being supplied to the various feed points through pipes. lti-stage system was never tested out in practice.

et torpedo propulsion. - (Herr Hans Ludwig)

ollwowing a report that he had been interested in an underwater sive duct, an interrogation was carried out on 15.6.45 of Herr g. Hans Ludwig, at Gross-Quern near Flensburg.

is man is an engineer employed originally at Argus Motore in Reinickendorf, and later at Blohm und Voss. He took out a for his water-jet engine which he called "Pulsomotor". The le is based on a patent taken out by Prof. Fottinger. Water is gentially into a round chamber through a non-return valve.

High pressure gases are then led into the chamber to increase the velocity of the water, thus giving a forward thrust. The advantages claimed for this scheme are (a) that it eliminates losses arising from cavitation at high speeds with a normal screw drive, and (b) that the motor occupies considerably less space for a given power output than a normal motor. He was aiming at a 70 knot torpedo and produced a design for the German G7m. torpedo which would give a speed of 50 knots with 1500 H.P.

Most of the work done was theoretical, though a few tests had been carried out with the pump, giving results described as satisfactory. Compressed air or steam was used for the fuel feed, though other fuels, in particular Ingolene, were proposed for ultimate use. Driven rotating disc valves controlled the air supply. The water speed at entry into the pump was about 10 m/s, the expected outlet speed being about 20-25 m/s.

It was eventually proposed to use three motors working at 10 cycles per second each and firing consecutively to give an impulse cycle at outlet of 30 per second to even out the thrust. 22 Kg. of oxygen and 7.3 Kg. of fuel (assuming a heat content of 10,000 KgCal/Kg.) would be required for a 100 second run, giving a range of 3000 m. Details of the pump appear in a paper by Föttinger in the organ of the Schiffbautechnische Gesellschaft of November 1936, entitled: Die Kohlenstaubturbine auf Grundlage der hydrodynamischen Arbeitsübertragung.

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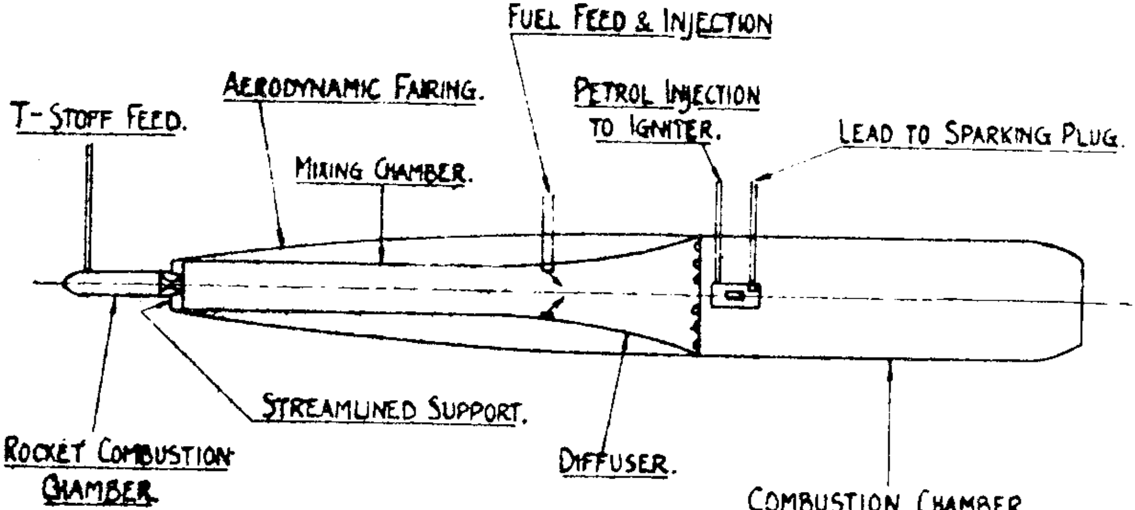

FIG 2. ROCKET - DUCT COMBINATION (RL - MOTOR)

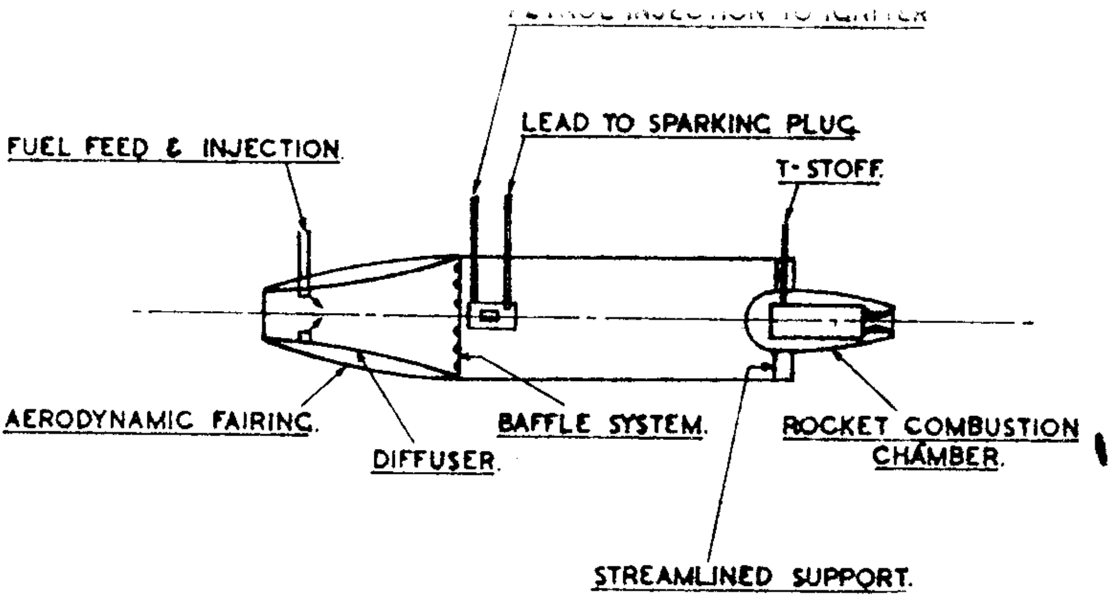

FIG. 3.- DUCT-ROCKET COMBINATION.
(L.R. MOTOR.)

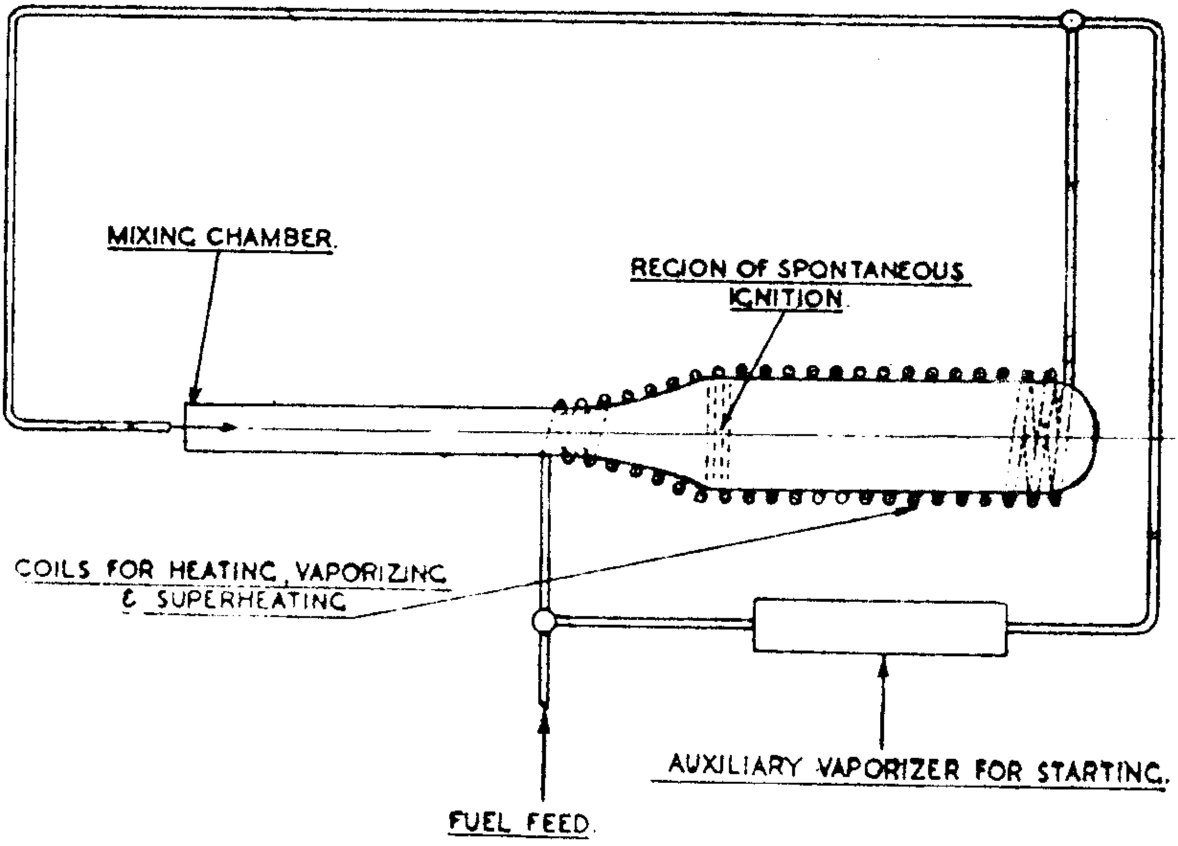

FIG. 4.- SINGLE FUEL METHOD.
(EINSTOFF R.L. MOTOR)

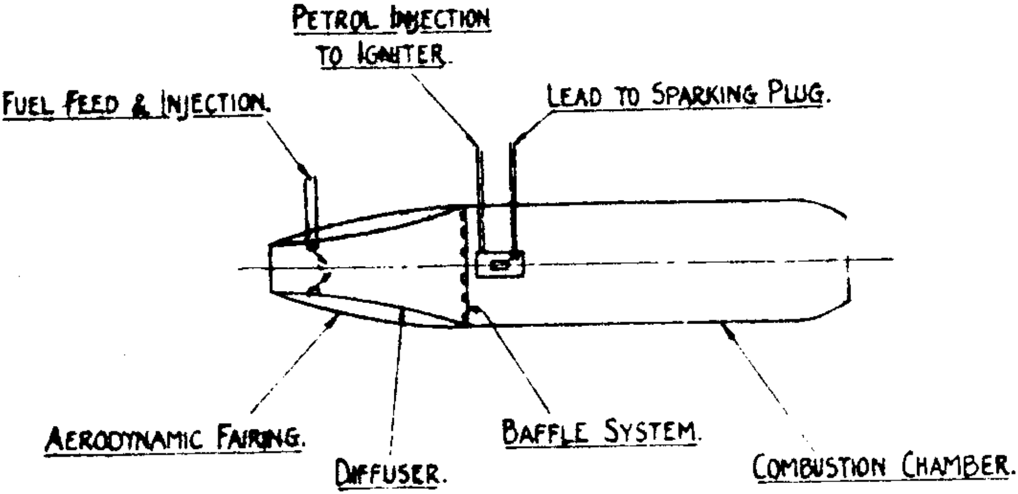

Fig 1. Propulsive Duct (L-Motor)

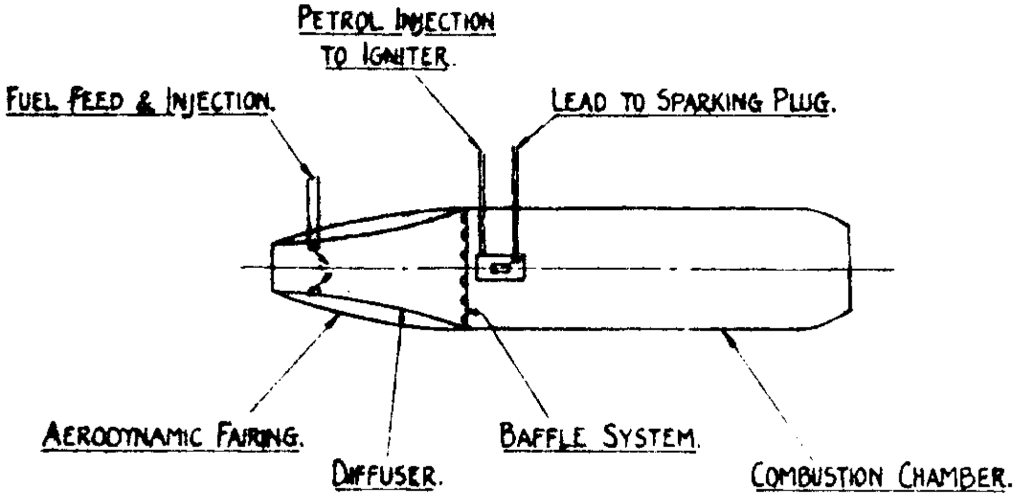

FIG 1. PROPULSIVE DUCT (L-MOTOR)

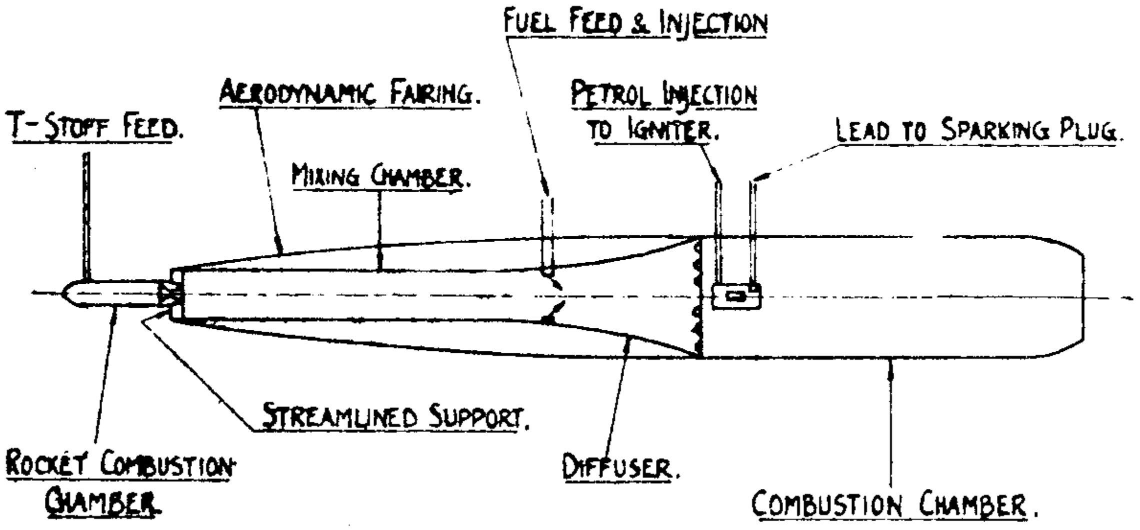

FIG 2. ROCKET - DUCT COMBINATION (RL-MOTOR)