A DOUBLE-SEATER CANOE

NEWNES

PRACTICAL MECHANICS

9d.

JUNE 1945

Rocket Propulsion

Further Rocket Motors Tested by the American Rocket Society : The Wyld Sounding Rocket

By K. W. GATLAND

(*Continued from page 267, May issue*)

ANOTHER test type produced by Truax was an uncooled propulsion unit developed under the auspices of the U.S. Naval Engineering Experimental Station, Annapolis.

Steel was used throughout in its construction, the convergent-divergent steel formed nozzle being protected by a refractory lining of alumina. Unlike the other Truax rocket units, this motor—designed to burn petrol as fuel, with oxygen obtained from compressed air—incorporated no cooling system.

Despite the lack of coolant, however, the motor proved highly effective under test; the efflux velocity being in the region of 5,000ft./sec., and during the most successful firings this resulted in a thermal efficiency of 40 per cent.

The Piecewiez-Carver "Nozzle-less" Rocket Motor

There was, too, a further concentric-feed motor developed jointly by N. Carver and C. Piecewiez. The former will be remembered for his work in connection with the concentric-feed propulsion unit of the Greenwood Lake mail-carrying aircraft. (PRACTICAL MECHANICS, February, 1945, p. 158.) In fact, the Piecewiez-Carver motor bore much resemblance to Carver's earlier design.

In the developed type the oxygen enters the combustion chamber through an axial opening in the motor "head," while the fuel alcohol is fed as a surrounding spray. The motor was actually designed to investigate the function of a liquid-fuelled reaction unit having no nozzle of the conventional tapering type, and the comburent efflux simply ejects through a length of constant section monel tubing, 8in. long by ½in. diameter.

The fuel and oxygen feed, particularly the method of supply control, is achieved both simply and effectively. The propellant components are introduced to the chamber through two lengths of copper tubing, each with a different bore, and so designed to provide just the required combustion ratio. Other than the variations of tube section, and the provision of inlet valves, there are no other devices or constrictions on the feeder lines, the injection ports being so proportioned as to provide a full tube-bore area.

Test Results

The motor's initial firing took place at Midvale on June 8th, 1941.

As there was no provision for internal ignition, the motor was fired by an internal fuse and an alcohol soaked asbestos strip. Prior to the firing, the supply pressure was adjusted to 300lb./sq. in., although, when the firing had commenced, this modulated to 260lb. sq. in., and remained constant. This was presumably the result of pressure drop in the feeding lines and regulating valves; no allowance having been made for the rapid flow.

When the motor was fired in testing the jet appeared as an enormous flame emanating from the "mouth" of the tubular orifice, and instead of the deep throated roar associated with the trials of more efficient types, the Carver-Piecewiez motor emitted a loud hissing noise. Clearly, combustion was largely effected as the mixture was leaving the nozzle; the combustion chamber merely acting as a mixing space.

According to "Astronautics," August, 1941, combustion lasted for eight seconds on a charge of 5.5lb. liquid oxygen and 9.8lb. alcohol. The reactive thrust was spasmodic at first, but settled down during the latter half of the testing run to about 42lb., when the jet velocity was approximately 600ft./sec. After the test the motor and feed lines were found to be frosted; confirmation that burning had not taken place inside the combustion chamber.

The Africano Refractory-lined Rocket Motor

Although many details of the refractory-lined motor, designed and built by A. Africano, are not available for publication, the data as derived from proving stand test is of particular interest. The Africano motor, in fact, achieved a record for the American Rocket Society during proving tests at their Midvale, N.J., testing grounds, in June, 1941, when a maximum thrust of over 260lb. was recorded.

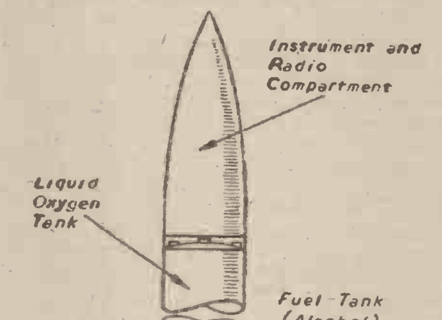

Fig. 24.—Diagram of the Wyld sounding rocket (1938).

The motor, which has a total weight of 23.5lb., incorporated a refractory liner of 8.5lb. Actually, in this instance the weight has little significance as the test motor was unnecessarily bulky and, in any case, intended purely for ground experiment. It has been estimated that only 4.5lb. of base structure was required to withstand combustion stresses with a reasonable factor reserve. The nozzle has a cone angle of 6 degrees; the "throat" being 15/16in. diameter, and the "mouth" diameter, 1.5in.

The designed chamber pressure was approximately 172lb./sq. in., for expansion to atmospheric pressure at 14.7lb./sq. in.

Test Details

On test, the Africano motor employed liquid oxygen, with denatured alcohol (11,000 B.T.U.) as fuel; the feeding being arranged through a gas system functioned by a nitrogen charging bottle.

Although it was reported that the test resulted in a maximum thrust in excess of 260lb., the true figure is not known because of the limitations of the recording instrument on the Society proving stand, which had provision for only 200lb. thrust. When the thrust gauge was later examined it was found that the mechanism had been badly strained, and was inaccurate for further work. A fair estimate for the maximum thrust figure was given by the designer as 280lb.

Upon ignition, the motor fired with a terrific roar, and immediately the gauge needle began to rise on the recording dial, falling back momentarily before continuing under pressure from the motor. This peculiarity, common to several motors tested by the society, is accounted to an initial explosion, which produces a pressure wave, temporarily cutting the fuel input. At only 2½ seconds of firing, the motor recorded a thrust of 85lb. The duration of combustion, which was limited by the amount of fuel available for test, was 12 seconds and the average thrust reaction, 184lb.; the amount of propellant consumed under these conditions being one gallon of denatured alcohol, and approximately 7lb. of liquid oxygen. The best performance was recorded in the ninth second of combustion; the jet velocity at that time being estimated at 7,050ft./sec., and the average flow about 5,140ft./sec.

At the period of maximum thrust, the jet flame could be observed at a distance of 150ft. from the nozzle "mouth," when a standing wave form was apparent near the nozzle, each being 4.6in. apart.

It was unfortunate that, just as the motor recorded maximum reaction, a portion of the refractory lining cracked and a great deal of the ceramic material was forced out through the nozzle. The figures given above cannot, therefore, be taken as highly accurate as the performance was affected by the increased nozzle area, which resulted in an increase of the jet flow. It was therefore impossible to gain any truly conclusive evaluation of the motor's performance.

The M.I.T. Liquid-oxygen Cooled Rocket Motor

Following the Africano motor test, a reaction unit developed by the Massachusetts Institute of Technology Rocket Research Society was bolted on the proving stand. The M.I.T. research group, then newly formed, is composed largely of students, some being connected with the institute in a research capacity, while a very few are entirely independent of the M.I.T. The rocket group, which carries out its work independent of the institute, was founded by Mr. E. C. Doyle in 1940.

The motor under review, which was designed by Mr. R. Youngquist, employed liquid oxygen as cooling medium and incorporated a jacketed lower chamber portion and nozzle. The liquid oxygen, after its passage through the coolant jacket, is finally injected for combustion as an annular gas spray toward the motor "head." The alcohol fuel, which is fed direct, is introduced in similar manner.

To aid starting, an alcohol soaked rag was tied in way of the nozzle and ignited. The propellant feed valves were then operated, and the motor fired effectively, emitting a loud roar.

The motor functioned for 13 seconds, returning a thrust of approximately 35lb. constant for the entire testing run. Unfortunately, however, just as the feed supply became exhausted, an explosion occurred which tore a large hole in the side of the motor and broke off the feed lines. A possible explanation of this was the detonation of an internal fuse, which had been left in the chamber from an earlier attempt to initiate combustion. This theory is substantiated by the fact that no part of the brass fuse casing was found after the incident.

The combustion chamber pressure throughout was 125lb., and the feeding pressure 250lb.

A.R.S. Rocket Motor

Concluding the day's experimentation, a replica of the motor which had powered the early American Rocket Society rockets, Nos. 1 and 2, was fitted for testing.

Designed jointly by H. F. Pierce and G. E. Pendray, the unit consists of a small egg-shaped combustion chamber, with inlet ports situated near the nozzle to inject toward the motor "head."

The motor is completely encased by a steel sheet-formed water jacket.

On test, firing was accomplished by an external fuse; the motor operating for fully 48 seconds—a duration record for the society—while developing a maximum reactive thrust of about 35lb. Apart from slight erosion close to the nozzle "throat," the motor was found to be undamaged.

Tests of the original motor in November, 1932, resulted in a maximum thrust of approximately 60lb., with a firing duration of 20 seconds, without injury to the chamber or nozzle.

Conclusions

From the foregoing it will be readily appreciated that the American Rocket Society has contributed much towards the development of liquid propellant rocket units, and remembering that the research was financed entirely by membership dues, and small sums donated by the experimenters themselves, what they have accomplished is truly remarkable.

These small test motors, which have now been developed to the stage when they can be operated repeatedly without burning out, are now considered to be sufficiently durable to power meteorological rockets for purposes of routine soundings of the upper atmosphere. The greatest height yet achieved by any man-made device is 98,000ft.—prior to the advent of "V2"—and this altitude, reached by a small Regener sounding balloon, is not likely to be much bettered by any device dependent on the atmosphere for lift.

The Wyld Sounding Rocket

Working from data obtained from the tests of his "regenerative motor" (see Fig. 24 PRACTICAL MECHANICS, May, 1945), J. H. Wyld published in 1939 the designs of a new sounding rocket. From the diagram, Fig 25, it can be seen that the projectile is of the tail-drive type; ballistically streamlined, and gyroscopically stabilised.

The rocket shell is cylindrical, with an ogival nosing and a conical tail fairing, the overall length being 9ft., and the maximum shell diameter, 5in. Four elliptical stabilisers—6 in. wide and 8in. overall length—are fitted just above the tail fairing, which incorporate movable rudders functioned by the gyros. These stabiliser fins are of ¼in. plywood, and pick up on studs attached to the rocket body.

The weight of the rocket empty is approximately 17lb., but this figure is increased to 35lb. when fully charged with propellant, 11.25lb. of liquid oxygen, and 6.75lb. of ethyl alcohol. Both tanks are filled, under complete loading, to a little more than half their full volumetric capacity.

Layout of Components

The propellant tanks are arranged in tandem; the upper tank, containing the liquid oxygen, being of monel, while the other is built of chrome-moly steel. The oxygen feed line, it will be observed, passes through the fuel tank.

As a precautionary measure, a safety disc, designed to fail at a certain critical pressure, is fitted in the oxygen tank.

For feeding the propellant, nitrogen gas is initially fed into both the oxygen and fuel tanks until a tank pressure of 250lb./sq. in. is reached. The inlet valve is then closed, and the feed lines disconnected. The tanks are, of course, pressurised on the launching, or test, apparatus, and the projectile fired immediately upon the attainment of the specified pressure.

The Gyro-stabiliser

The gyro is so designed to hold a true course within 10 degrees. It has a diameter of 4in. and is mounted at its centre of gravity on small gimbals. The complete unit has a weight of ¾lb.

Prior to a free flight test, the gyro is run up to an initial 10,000 r.p.m., and at this speed its momentum is sufficient to serve effective control for the entire flight period. In consequence, no integral driving motor is required.

According to the designer, the control device is made up as follows: The lower end of the gyro axle carries light valve rods. These connect to small slide rods, which, in turn, control the motion of servo-cylinders sliding on stationary piston rods, there being two such cylinders fitted at right angles. Each of these control one of the rudder shafts through rudder levers and they are supplied with pressure via two flexible tubes leading to the gas-space in the fuel tank. A small auxiliary tank (not shown in the diagram) is employed to supply pressure after firing has ceased and the pressure in the main tank is exhausted.

Another novel feature is the parachute ejecting method. As can be seen from the diagram, the parachute compartment is located at the rear of the rocket—just above the gyro—and by this arrangement the rocket is brought to the ground nose first.

The gyro itself acts as the parachute release. An insulated ring is fitted about the vertical axis of the gyro, so that when the rocket curves at the zenith of its trajectory, the ring deflects and makes contact, so closing an electrical circuit which fires an ignition fuse embedded in the powder charge of the ejecting device. This is simply a short tube, containing the charge, separated from a small pilot 'chute. The pilot 'chute, is, of course, attached to the main supporting parachute, which it pulls out through an access door in the containing compartment. This method of release, incidentally, was first suggested by Mr. Street, of Providence, and Mr. H. F. Pierce (A.R.S.), both working independently.

As a safety measure, an auxiliary device, which functions under tank pressure, is also provided, being so designed that release cannot occur until the propellant is exhausted.

Although no details of any flight trials are available—presumably the war caused a postponement of construction—the rocket is estimated to be capable of an upward range of a minimum of three miles.

Payload

There is provision for a payload of 2lb., which would consist of meteorological recording apparatus, and possibly a light radio transmitter. Whether a suitable apparatus, effective, yet sufficiently light and compact, is available for a rocket of this size is questionable, but, in any case, transmitters will be a very necessary fitment in the larger sounding projectiles now under development. These rockets will be located by radio, making use of two ground receivers, the position being calculated by triangulation.

Operating Costs

The cost of each firing has been estimated to be in the region of 25 shillings; this being the cost of propellant.

Manufacturing costs, too, would not be great for such a small rocket, but it is obvious that if we are to produce the larger rockets, which are the sole means of charting the upper reaches of the atmosphere, such development cannot be achieved through the sheer enthusiasm and technical ability of "amateur" investigators alone. The rocket has now reached a point where no appreciable gain can result from "private enterprise" that is not backed by substantial funds, and we can conceive no rocket society whose membership would yield the huge sums required. It now remains for State subsidy to provide the necessary financial support for this further important development.

(*To be continued.*)

One of the V2 rocket bombs captured intact by the U.S. First Army in Germany.