

A.R.D.E. Summary of Progress

1. Thrust Vector Control

Preliminary copies of the report on the optimum nozzle length theory have now been circulated as agreed at the last meeting.

Further experiments are proceeding with nozzles with an 18.5° exit cone angle using an improved design of inlet cone and throat to avoid the formation of a vena contracta.

Tests are in hand with the 8-inch rocket with a view to checking the nozzle theory by comparing the dispersion of the rocket when fitted with nozzles of optimum and non-optimum lengths.

2. Anti-tank G.W.

Work has continued on the attempts to improve the accuracy of the Malkara anti-tank guided missile during the boost phase. Small scale nozzles of the same exit cone angle and expansion ratio as the Malkara nozzle but of a size suitable for use in the "All-forces dynamometer" test-rig have been made and experiments have commenced to determine the optimum length for accurate gas alignment.

The larger scale thrust alignment test-rig designed for firing motors of the order of 7-inches diameter is now nearly complete and will be tested with a "Demon" motor shortly. The rockets in this rig are fired horizontally and reliance will be placed on the measurement of side thrust in the horizontal plane at a point near the nozzle throat. It is considered from experience with the "All-forces dynamometer" that this information will be adequate for predicting the behaviour in flight of most rockets. The rig is being adapted to take the Malkara motor. Tests will be carried out on the original Malkara nozzles with duresstos type throat and exit inserts, which are being obtained from Australia, on new all-steel nozzles of the same shape made here and on modified steel nozzles of the optimum length as determined by the small scale tests. From firings already carried out here considerably less erosion is expected with the steel nozzles.

Further tests have been carried out with the 8-inch test rocket fitted with wings (Quickfire) as a possible solution of the short range accuracy problem discussed in the last report. In these adjustable elevator flaps were fitted to the rear of the wings to control the angle of incidence of the rocket in flight. This trial was more successful in that the lift was reduced and hits were achieved at 150 yards range. However at the launching elevation used tip-off drop was too large and a dip occurred in the rocket flight some 50 yards down range. The tests will be repeated using increased elevation and with horizontal fins of increased size.

3. New anti-tank Rockets

Further static firings have been carried out in connection with the development of short burning charges for the 100 mm. rocket. These use disc type charges resembling the Heller rocket but with increased loading density. The discs are supported on a stepped four-stage perforated metal support and difficulties have been experienced due to collapse of this support under the high temperature and high pressure-drop conditions. These difficulties have possibly been aggravated by the use, pending the development of a more suitable propellant by E.R.D.E., of propellant F488/807 at near the upper limit of its

The soil erosion but the reduction does not appear to be sufficient, a diffuser being markedly more effective.

Soil erosion tests are starting in a few days in which conical inserts are being placed in the nozzle. These are designed to form a powerful shock at the rear of the nozzle. Two types of inserts are being used which reduce the Gosling thrust by 1% and 3%. It is intended that these be discarded after 0.4 secs. at which time the forward velocity of the missile is approximately equal to the calculated ejection velocity of the insert which can be designed to break up after leaving the nozzle. The inserts would be sufficient to eliminate the soil erosion due to the upper boost and small diffusers on the launcher should be sufficient to defeat the lower boosts. Boost blast pressures should be considerably reduced; these will be measured in the trials. The success of this scheme depends on the results of the ballistic analysis now proceeding, since the missile deviation must be kept small. Preliminary results indicate the method to be feasible.

As a preliminary to the launching trials of the "Blue Water" missile at Eskmeals, simulated trials were carried out in Woolwich with an identical launching vehicle, the missile itself being replaced by two 8-inch rockets held statically and fired simultaneously. These give a total thrust of 28,000 lbs. for 0.2 secs., the geometrical arrangement being similar to that intended for the full missile. The rockets were fired on soil, with and without a steel plate and on a concrete pathway, and the damage to the vehicle assessed in each case. The results indicate that firing directly on to soil would be unacceptable, there being very severe debris and the lorry sank in the crater formed. There was only slight damage to the vehicle in the firings on concrete and almost negligible damage in the firings on the steel plate. These conclusions have been confirmed in the firings at Eskmeals. The soil firings were repeated with diffusers attached to the rockets, the soil erosion was very much reduced and there was no visible damage to the vehicle. The initial height of the nozzle of the Blue Water missile above the ground is too small for a diffuser to be fully effective and the best solution appears to be a diffuser together with a small steel plate placed at the position of impingement.

5. Jet Deflection Tests

Some preliminary experiments of a fundamental nature have been carried out, a simple configuration being used which could also be examined theoretically. A cylindrical extension piece was attached to the nozzle of an X.D. rocket. By cutting out segments of this extension piece, lateral forces were obtained. A low exit cone angle of 14 degs. was employed with an expansion ratio of 6:1. The length of the extension piece was equal to the radius of the exit of the nozzle. The lateral forces were measured on the "All-forces dynamometer". The theoretical value of the thrust deflection at ground level is $56 \sin \theta / 2$ mils, θ being the angle subtended by the cut away section at the centre. The experimental values fitted very closely to this curve for values of θ between 0 and 180 degs. Four rockets were fired for performance index, two with and two without the full extension piece and there was no measurable difference. These results suggest the shock wave is attached to the junction on the extension piece and the nozzle.

The experiments are being repeated with a 30 degree exit cone. The theoretical thrusts deflections are then.

$$150 \frac{1}{a} \sin \theta / 2 \text{ mils, } A_e / A_t = 6:1,$$

$$108 \frac{1}{a} \sin \theta / 2 \text{ mils, } A_e / A_t = 4:1.$$

1 being the length of the extension piece and a the radius of the nozzle exit. These formulæ are valid only if there is no separation of the jet in the nozzle. For zero ambient pressure these values must be increased by approximately 20%.

Ordnance Board trials for the Tandem Piston Gas Generator have been commenced. A contract has been placed for 500 igniter bodies for delivery in accordance with User Trial programmes. This order was placed with Messrs. Armstrong Whitworth at their request. The igniter bodies are two months overdue to date. Charges have been obtained from Bishopton and a number have been supplied to Messrs. Armstrong Whitworth for trials. A.R.D.E. with the assistance of Messrs. Microcells have designed a service package to house 5 in number charges and 5 in number igniters. Requisitions have now been placed for a supply of boxes, rubberised moulding packing, polythene capsules for the charges, and polythene bags for the igniters. These packages should be available within the next three months. A.R.D.E./X.4 has undertaken to supply igniters, charges and packages for Ordnance Board trials and for User Trials.

(c) Cartridge, Initiating I.P.N. Gas Generator for G.W. (Sea Slug)
Standard Power Cartridge

A.R.D.E./X.4 have continued their work on the design for an adapter to fit the Armstrong Whitworth breech such that a Standard Range design of Power Cartridge could be used. This work is nearly complete and it will remain now to design the ballistic characteristics of a $1\frac{1}{4}$ -inch Standard Range cartridge.

(d) Power Cartridge for remote activation of reserve battery in G.W.
McMurdo Instrument Company)

No further experimental work has been carried out during this period due to the pressure of more vital work.

(e) Power Cartridge for fuel valve closure (I.C.B.M. Rolls Royce)

A.R.D.E./X.4 were approached concerning the design of Power Cartridges for the operation of two fuel valves. This work would have been most advantageously done by X.4/A.R.D.E. but owing to extreme shortage of staff it was placed on the I.C.I. Comapnay, Ardeer, by A.Arm.1.

(f) Power Cartridge for battery charging electrolyte injection (Joseph Lucas)

Preliminary discussions have been held. A.R.D.E./X.4 have advised on the behaviour of Power Cartridges associated with this apparatus. Elementary trials in a simple breech design manufactured by Joseph Lucas have been carried out at A.R.D.E., Langhurst. Following this a further set of trials were carried out at Langhurst with the representatives of Joseph Lucas Company present. These trials were carried out on a prototype rig and, as reported by the Joseph Lucas Company, provided them with valuable information such that they could continue with their design. It is envisaged that A.R.D.E./X.4 will not be able to make any great contribution in the future due to the extreme shortage of staff.

(g) Power Cartridge for Rocket Stage Separation (R.R.E.)

Preliminary discussions have been held at A.R.D.E./X.4 and R.R.E. Malvern have been advised on the application of a Power Cartridge to suit this purpose. A letter has been received from R.R.E. dated 18th June, stating that they are building a mock-up rig and would like to carry out some elementary trials in August. A.R.D.E./X.4 have recently had to notify R.R.E. Malvern that they are not in a position to continue due to shortage of staff.

plateau range. However, these difficulties have now been overcome, it is believed, by the use of additional head-end suspension for the support, increasing the cross-sectional area of the support, and increasing the area of the separators between the discs. The support is made of mild steel and is protected from heat by a layer of polythene 0.01-inch thick deposited on the outside. Supports made of 1% chrome molybdenum steel, stainless steel En58, Nimonic 75, and chromium plated steel some with alternative sized perforations are being made and tested as an insurance, particularly for the higher stresses under flight conditions. No difficulty with ignition has been experienced with F488/807 with the present charge design and the specific impulse has been very satisfactory.

The investigation of the launching conditions of spin stabilised rockets from a curved rail launcher has continued. For this purpose a number of 100 mm. spin stabilised rockets were dynamically balanced carefully by cementing lead discs of suitable weight to predetermined points at both ends of the rocket. These balanced rockets were fired from the curved rail launcher against an equal number of production unbalanced rockets and the variation in angular velocity at a point 70' from the front of the launcher measured photographically. This fell from a value of 1.9 degrees m.d. for the unbalanced rockets to a value of 0.7 degrees for the balanced rounds. For a spinning projectile this latter figure is considered to be very satisfactory and it is concluded that a curved rail launcher is suitable for launching spin stabilised rockets of this type as well as for fin stabilised rockets. These tests were carried out using rocket charges which were designed to be all burnt on the launcher. A certain amount of tail-off burning may, however, have occurred outside the launcher and it is considered it might be of value to repeat the trial with charges in which this doubt has been removed.

4. Soil Erosion and Boost Blast

Analysis of the records of the trials of the "Red Shoes" missiles with short burning charges carried out at Shoeburyness and the similar records taken at Aberporth with the two missiles with full charges is complete. A detailed theoretical ballistic analysis of these missiles is near completion and a report will be presented shortly.

Two results already emerge.

- (i) The steel mat which was so successful in the Shoeburyness trials was equally successful in the firings at Aberporth with the full missile.
- (ii) The boost blast pressures downstream of the missile measured at Shoeburyness and Aberporth are appreciably lower than those expected from the extensive measurements carried out in America on the pressures in deflected jets, the results being nearer to those we expect from our own small scale trials. It appears that the nature of the ground surface affects the results. This is being investigated in trials with the 8-inch rocket. The rockets are being fired onto concrete, a steel plate and a Hypalon mat, the latter suggested and supplied by I.C.I.

Trials are now proceeding with the "Red Shoes" missile with short burning charges with diffusers attached to the launcher. The preliminary results show the diffusers to be satisfactory.

Soil erosion tests have been carried out with the 8-inch rockets in which the single nozzle was replaced by a multi nozzle arrangement. The photographs show that the emergent jets recombine into one single jet and at the position of contact a powerful shock is formed. This appreciably reduces

6. Post Design Services; Motor Rocket 3" No.13 (Coastguard)

The troubles mentioned in the last report seem now to be cleared up. The investigation has drawn our attention to a matter which has an interest beyond the immediate problem.

It appears that there are several lots of propellant in the consignment delivered to the Ordnance Factory for assembly into these motors; by chance it happened that the trials in this Establishment were carried out with lot BS.23640, and those arranged by the factory and the inspection authorities with BS.23639. There was no a priori reason to suppose that these successive lots, made to fulfil the same demand, would differ. Other possible variables, such as the batch of magnesium used in the igniter, were eliminated by comparative trials, and meanwhile the perimeter of the star shape, which is proportional to the initial burning surface, was measured on some charges taken at random. The mean perimeters were:- lot BS.23639, 8.6-inch; lot BS.23640, 8.95-inch; lot BS.18501 (earlier lot which had been declared satisfactory by the Coastguard Services) 9.4-inch; design perimeter, 8.65-inch. A trial with lots BS.23639 and BS.23640 was arranged, filling and firing to be entirely carried out by the appropriate authorities, so as to exclude any possible effects of our own specialized experience. The result was as predicted lot BS.23639 failed and lot BS.23640 functioned correctly. It was remarked in the last report that the design working pressure of this motor is near the critical pressure for early burning failure, and it seems clear that the burning surface of some of the charges of lot BS.23639 is insufficient to develop a pressure above the critical, at the lower temperature limit. As the perimeter of this lot is close to the design perimeter, it is evident that the present Service design differs from that used when the motor was originally designed and passed its initial trials successfully. The observations on the earlier lot BS.18501 support this opinion. We still have to measure perimeters of sufficient charges to enable us to determine the spread of perimeter in each lot; it is of course unlikely that all charges of BS.23640 will be satisfactory. The proportion of failures in lot BS.23639 at -5°F . is about 30 per cent.

A satisfactory method of inspecting a charge shape, such as that of the No.13 motor, has not hitherto been developed, and specifications are nebulous in respect of burning surface. The manufacturing and inspecting authorities concerned cannot therefore be fairly criticised for the misbehaviour of this rocket; in fact the charges which fail are often nearer to the current design than those which function correctly. The present investigation shows the need for a clear specification of burning surfaces, and also indicates a possible method. The method preferred amongst others tried, was to cut slices off the charge with the trimming machine, mount the slices between glass plates, and project on a Taylor-Hobson profile projector. The perimeter of the image was then measured with a map-measurer. This method of inspection would enable acceptance limits of perimeter to be specified with the assurance that an inspecting officer could pick out all charges failing to conform; it is likely that only a small proportion, less than 1 per cent of charges would need inspection in this way. It is proposed to raise this matter at the next meeting of the Panel for the Control of Quality of Rocket Propellant Charges.

7. Power Cartridges for use in Guided Weapons

(a) Cartridge, Initiating Plessey I.P.N. Power Pack for G.W. (Black Knight)

The Plessey Company have been supplied with 20 in number $1\frac{1}{2}$ -inch Power Cartridges for test firings in their I.P.N. Power Pack. It is understood that these have been fired with reasonably successful results, but A.R.D.E. is still awaiting a full test report.

(h) Power Cartridge for the Jettison of Recording Equipment (Black Knight)
R.A.E. Farnborough

A.R.D.E./X.4 have been approached by R.A.E. Farnborough to give advice and consultation on the ballistic performance of a jettison device designed by them employing the cartridge they have had made up by Messrs. Shermuly. From preliminary discussion it is evident to A.R.D.E./X.4 that R.A.E., Farnborough are greatly in need of advice and specialist assistance, but A.R.D.E./X.4 are not in a position to offer any constructive help at the present time due to the shortage of staff.

(i) Projects as itemised in paragraphs e, f, g and h represent relatively new work which the department is unable to accept due to a shortage of staff. The staff position and the capacity of A.R.D.E./X.4 is at present under review of C.M.

A.R.D.E.
Woolwich
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