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A "SPORTS" PEDAL-CAR

NEWNES

PRACTICAL MECHANICS

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EDITOR : F. J. CAMM

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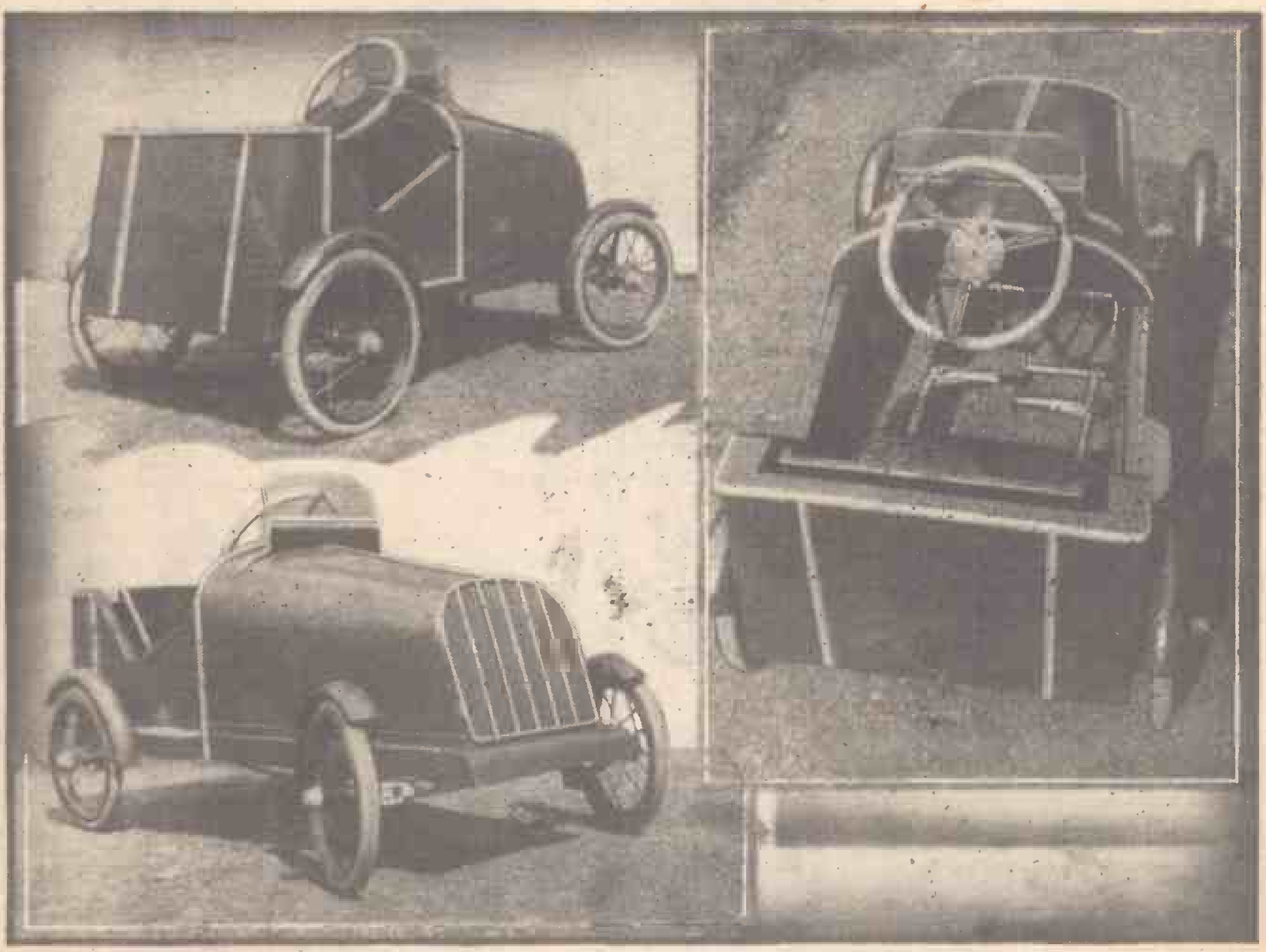


A STURDY "SPORTS" PEDAL-CAR. *(For Constructional Details see page 8).*

PRINCIPAL CONTENTS

Rocket Propulsion

The Transatlantic Rocket

By K. W. GATLAND

(*Continued from page 387, September issue*)

"THE design of true *spaceships* is all but practicable to-day, and research will bring them into being in the foreseeable future," so wrote H. H. Arnold, Commanding General of the United States Army Air Forces, in his Third Report to the Secretary of War, dated November 12, 1945.

The statement evoked no great surprise. It merely emphasised what the V-2 had made seem perfectly logical, and though we may doubt whether the U.S.A.A.F. will succeed in reaching the moon with a guided missile inside eighteen months—as was predicted by one of its spokesmen a year ago—there must be few who do not recognise the immense implications that now lie ahead in the development of rockets for the navigation of space.

The "A" Programme

What has already been accomplished in the realm of long-range rockets is due almost exclusively to von Braun and his technicians at Peenemunde where, in the middle "thirties," Hitler had built an expansive rocket development station at a cost of 300 million Reichmarks.

There is little that need be remarked about the V-2 as very complete accounts of the design and operation of this missile have been published elsewhere.

Not so widely known are the other projects which Braun had under development. One was an improved, winged, V-2 (the A-9) for use against England; the second (A-10), a much more ambitious project to extend the range of the adapted V-2 to the Atlantic seaboard of America, and the third, a giant three-step combination rocket for scientific investigations *beyond the atmosphere*. This final development was aimed at getting a modified V-2 to take up an orbit around the earth 400 miles from the surface.

The accompanying table shows that Germany embarked upon military rocket research as early as 1933 and that by 1940 the necessary data had been acquired with which to formulate the design of really powerful rockets—and one in particular, the A-4, which was later to be fired against London as Hitler's second "revenge" weapon, V-2.

Origin of the V-2

The A-5 was the experimental prototype for the later A-4 and was launched in hundreds between 1936 and 1942 in studies of aerodynamic, control and stabilisation problems. It was of particular importance in being the first rocket to employ *graphite* vanes in the jet-stream.

The larger A-4 was 45ft. 10in. long and had a maximum diameter of 5ft. 5¼in. It weighed 12.48 tons when fully fuelled for take-off and developed an initial thrust of 24.7 tons.

Main individual weights were as follows: propellant (liquid oxygen and a 75 per cent. solution of ethyl alcohol), 19,310lb.; power plant (complete with turbine and ancillaries), 6,320lb.; Amatol warhead, 2,150lb.

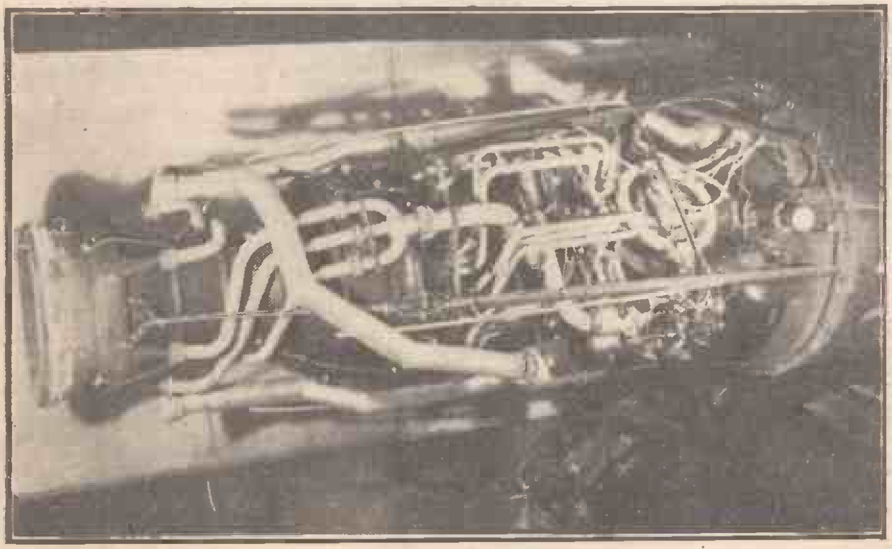
The specific impulse at ground level was 210 seconds (mean), but the high figure of 222 seconds had been recorded on occasions during German tests. It would be interesting to know how this maximum figure compares with the figures now being obtained by U.S. Army technicians in New Mexico, where, earlier this year, a modified V-2 travelled to a height of 111 miles.

Adapted for the U.S. Army for scientific soundings of the upper atmosphere, this V-2 is seen here being readied for flight at White Sands, New Mexico.

Control

It was the four *internal* gas-stream vanes that provided the main controlling effect during the initial 10 to 15 seconds of flight, and their influence was most noticeable just as the rocket left its launching base, when the ascent appeared amazingly slow and yet was obviously well controlled. The external fins and airstream vanes could not possibly have exercised any influence in those first critical seconds, and again it is not too apparent that they had much effect even when the V-2 moved at about 3,400 m.p.h., by which time the rocket would have reached an altitude of 23 miles, where the relative density of the air is at the low figure of 0.0053.

The two sets of steering vanes were linked, and in the earliest V-2s pitch and azimuth gyroscopes were used to control them, opposing any deviation from course by a counter deflection of the jet and air-stream.



The V-2 power plant. Weighing 6,320lb. (less tanks), it developed fully 60,000lb. thrust for 70 seconds.

The Integrating Accelerometer

A cut-out gear was embodied to ensure that the rocket fell within the target area and worked when it had reached a velocity of 5,100ft. per second, velocity being the main determinant of range. Thrust ended some 70 seconds after take-off and impulse carried the missile 37 miles beyond that point as it described a parabolic curve, turning slowly back to earth 60 miles high. The average *distance* travelled by V-2 was between 180 and 190 miles.

In 90 per cent. of the rockets fired on London it was found that a specially developed *integrating accelerometer* had caused the cut-out, but in later missiles (including the A-9) a *double-integrating accelerometer* had been incorporated.

This latter scheme was a great improvement. A first accelerometer controlled the revolutions of an electric motor, the angular velocity of which was always proportional to the missile's velocity; in the second stage the number of revolutions were automatically counted to give the distance travelled, functioning only when a preselected figure had been reached.

After V-2

The A-9 (Fig. 96) had been formed by the simple addition of 75 sq. ft. of wing to the A-4, the power plant and all essential components remaining unchanged. Thus it was planned that the bombardment range of the basic missile should be extended by at least 100 miles—and this without resorting to a smaller warhead.

Operation of this winged rocket would be near enough the same as adopted for the A-4, which stood upright on a flat concrete base and rose vertically. In the latter case an internal mechanism was designed to move the missile into a 45-degree angle after reaching an altitude of eight miles, and this phase was completed about 52 seconds after take-off.

The addition of wings would naturally have modified these figures by virtue of the increased weight and extra drag, although it is true that they would not have incurred anything like the same resistance in the much thinned atmosphere through which the rocket moved 30 seconds after take-off. In point of fact, the adapted missile would not have risen anything like so high. The zenith of its calculated trajectory was little more than 18 miles, the path of which was near parabolic at the top and automatically controlled. The rocket was intended to cease thrusting just as it began to turn horizontal to the surface prior to curving back to earth.

The design was such that as the wings struck denser air, aerodynamic controls on the fins helped the A-9 into a glide, and it would finally hit the ground some 300 miles from the point of ascent, having been in flight about 15 minutes. Impact with the ground would be made in a dive which would occur when the rocket's speed dropped to sonic values.

The A-9 cannot, of course, be classified as a rocket aeroplane, for it could perform aerodynamically only after the thrust period, when the tanks had been drained and the all-up weight was 4 tons, as compared to over 12½ tons at take-off.

A-9 on Test

The Germans produced some experimental A-9s during the winter of 1944-45, and one or two had actually been launched in stability trials before the Allies took charge.

The results were disappointing in the extreme. Though the rockets were steady enough at take-off, it was clearly apparent that as speed increased, an oscillation of increasing amplitude was being set up which the gas-stream vanes could not fully overcome. This quickly developed into a jerky, zig-zag motion which one might liken to the vicious swinging of a harpooned whale, and each missile exploded in the ground.

These, however, were initial tests. It might be remarked that the "teething" stages of V-2 development were equally troublesome; the first missile of the series (fired on July 6, 1942) rose about 3ft. and then exploded; the second climbed some 16,000ft. and exploded, as also did the third. The fourth was completely successful and travelled 170 miles.

It would undoubtedly have been much the same story with the A-9 had Braun and his colleagues been allowed more time for research.

Improvements were on the way, and it was confidently expected that, had the war continued, winged V-2s would have begun to flow from underground factories by the summer of 1945. The London area and some parts of the Midlands would then have been brought within range from bases in Germany.

The nozzle end. At the root ends of the four fins are the plates which hold the graphite vanes. Shafts from these extend into the fins and link up with the airstream vanes so that both sets of controllers work in tune with the controlling gyroscopes.

The Transatlantic Project

A large proportion of German production had been gambled on providing means for desolating London and other European cities, and nothing would have pleased Hitler more than to rain bombs on New York as a grand climax.

A dream? Perhaps! But not without some foundation.

The Spanish Civil War had given Hitler definite ideas about bombing, and accordingly he set to work on providing the means with which to penetrate the weak spot which his reasoning told him lay in the civilian population. The early part of the war saw Germany producing bombers on a large scale to make the Luftwaffe an invincible force wherever it chose to operate. And when, later, the Luftwaffe failed to bring off the seemingly inevitable over London and the provinces, a large part of German industry was switched over to building the flying-

Code No.	Year	Length (ft.)	Dia. (ins.)	Weight, Total (lbs.)	Weight, Propellant (lbs.)	Thrust (lbs.)	Thrust Duration (secs.)	Specific Impulse (secs.)	Remarks
A-1	1933	4.6	11.8	330.6	88.2	661.0	16	143	Directly stabilised by one large gyro in nose. N_2 pressure feed. Nine launched, vertically.
A-2	1934	4.6	11.8	330.6	88.2	661.0	16	143	As A-1 but with gyro in centre. Maximum height attained, 6,560ft.
A-3	1938	25.0	30.0	1,653.3	992.0	3,306.0	45	167	First rocket to use gyro-steering vanes in jet stream. Reached an altitude of nearly 40,000ft.
A-4	1940–1942	46.0	65.3	27,556.0	19,310.0	60,000.0	70	208	Popularly known as V-2. Most effective of all rockets built in Germany. Range, 180–190 miles.
A-5	1938	25.0	30.0	1,653.3	992.0	3,306.0	45	—	Experimental prototype of A-4. First rocket to use *graphite* vanes in jet stream. Maximum range, 11 miles.
A-6	—	—	—	—	—	—	—	—	Sub-sonic project—design only.
A-7	1941	25.0	30.0	1,763.6	1,102.0	3,306.0	45	—	A-5 plus wings. Experimental prototype of A-9 and Wasserfall defence missile.
A-8	—	—	—	—	—	—	—	—	—
A-9	1945	4.6	65.3	28,658.0	19,310.0	60,000.0	70	208	A-4 plus wings. Maximum range, 300 miles. Prototypes under test at time of surrender.
A-10	Project 1945	—	—	191,780.0	136,680.0	440,840.0	50	166	Booster for A-9 intended to extend the range to 3,500 miles; exhaust velocity, 53,000 ft./sec.; jet flow, 2,728 lb./sec. N_2 pressure feed.

The "A" programme of rocket development which, under Hitler's direction, German technicians commenced in 1933. Highspots of the work were: A-3, the first rocket to use gyro-synchronised vanes in the jet stream; A-5, small-scale prototype of A-4 with graphite vanes; A-4, operational missile known as V-2; A-9, winged V-2; and A-10, booster for A-9. Each was specified to employ liquid oxygen and ethyl alcohol as propellant.

Table showing German rocket development.

The secret of V-2's perfect stability at take-off was in the four gyro-synchronised vanes, made from graphite, which worked in the jet stream.

giant missile failed to lift but merely toppled. It was bad enough when a V-2 fell over on its launching base, and this happened on more than one occasion.

There can be little doubt that some form of launching tower would have been necessary, and even more so with the *atomic* warhead which it was hoped that German scientists would have ready by the time the project was in full-scale production.

Two-Hundred Tons' Thrust

The two-step rocket would have ascended in much the same manner as the V-2, with the A-10 supplying fully 200 tons' thrust for the first 50 seconds of flight. The booster was intended to release automatically with the falling off of thrust, dropping astern as the A-9 moved off under its own power. The smaller rocket would accelerate rapidly in the highly attenuated atmosphere through which it moved 16 miles above the surface, building up on the imparted velocity of 5,000-ft. per second. This, it was reckoned, would result in a peak altitude of about 45 miles, the control of which was to be similar to that adopted for the single A-9.

It was considered that a maximum velocity of 9,200-ft. per second might easily be attained as the missile began its plunge earthward. With this great amount of kinetic energy to dissipate in the lower atmosphere, it is quite feasible that Braun's claim of 3,500 miles range for the boosted A-9 is within the bounds of reason. The figure, unfortunately, is impossible to check with the small amount of data available.

The missile would be brought into horizontal flight with the aid of automatic controllers, the remainder of its travel taking effect in an extended glide, in which it was expected that no height at all would be lost during the first several hundred miles after levelling out. The flight was planned to last 45 minutes.

Meanwhile, the A-10 would have begun to drop back, the release of a multi-parachute gear by a special timer permitting the empty component to drift slowly to the ground somewhere over France for collection and re-use.

Self-inflating Parachutes

The parachutes considered for this project were of a special design to enable them to open, despite the rarefied nature of the atmosphere. Each was to have double panels in its canopy which inflated from compressed-air bottles situated inside the rocket body. When fully spread, they would form a semi-rigid structure which gradually took effect upon the atmosphere, serving as a gentle brake for several miles until the condition of free-fall was safely arrested.

Had parachutes of a standard pattern been used, they would certainly have been torn to pieces as the A-10 plunged through air of rapidly increasing density and became subject to violent pressures.

The Question of Altitude

It will have been noticed that the boosted bomb, and when eventually this weapon also ceased to bring the results expected, it was the turn of von Braun and his V-2.

The advent of so long-ranging a rocket brought fears that many at the time were not prepared to admit. Against it there was no defence but the prompt despatch of fast fighter-bombers to strafe the launching sites and supply trains; the wholesale bombing of storage depôts and production centres.

Eventually it became possible to occupy the territory from which the missiles were fired and so force the launching sites deeper inland and at length to make them wholly ineffective because they could no longer reach the London area.

This was the main reason why, right up to the surrender, German technicians were hard at work striving to perfect the A-9.

Berlin to New York

When Allied technicians conducted their examinations of Peenemunde shortly after the surrender, they found among the vast files of rocket data the first indications of a long-range missile beyond A-9. This was the project A-10, a giant 85-ton booster on to which the A-9 was designed to fit as a second stage. It would have its purpose in accelerating the smaller winged rocket to a velocity sufficient to carry it across the Atlantic, with the object of exploding in New York or in any other city within its 3,000 to 3,500 miles range.

The A-10 was more than an idea. Its development had passed the preliminary engineering stage, and if Braun's estimates are to be relied upon, it could have been built and ready for action within a year of the war's ending.

Take-off Hazards

It is not known exactly how it was proposed to launch the A-9/A-10 combination, for the aggregate weight worked out to nearly 100 tons. The "flat-base" technique would have been too dangerous for a rocket of this size for reason alone of the amount of propellant it carried—about 79 tons at take-off—plus a 1-ton warhead, which, to say the least of it, would have put paid to the launching site and any of the operating crew who remained in the vicinity had the

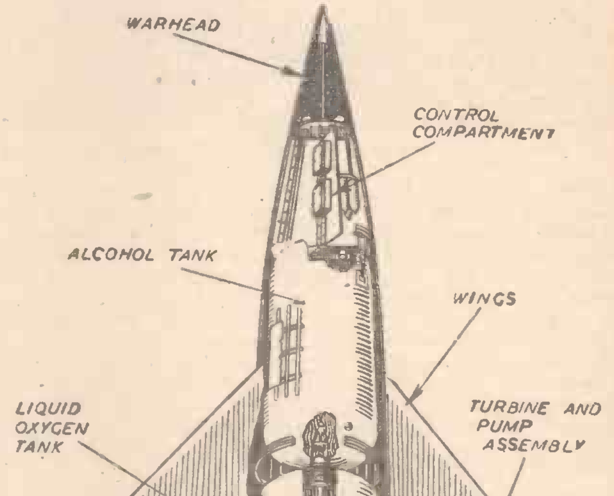
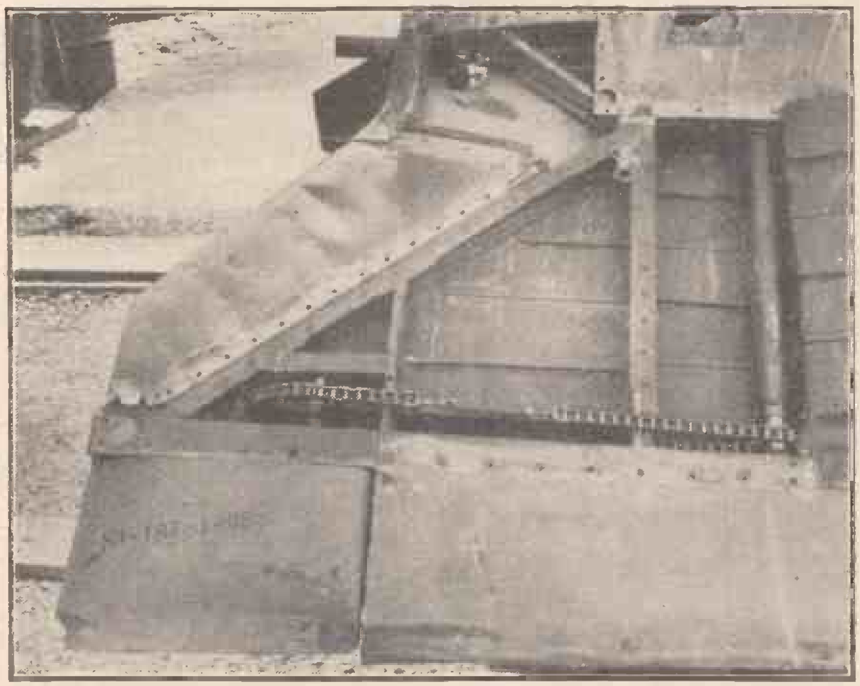


Fig. 96.—How the Germans were about to adapt the V-2 is shown in this cut-away drawing. The addition of wings would have increased the range by at least 100 miles. In a later project an 85-ton boost rocket was to accelerate this A-9 to a speed of over 3,000 m.p.h. before it began thrusting on its own account. A final speed of about 8,000 m.p.h. would have enabled the missile to glide in the denser atmosphere and (it was calculated) to reach territory in the region of New York within 45 minutes. A still later development in conjunction with a 200-ton booster was to enable the missile to carry a pilot.



The simple arrangement of the airstream control-vanes, one in each fin, is apparent in this photograph.

A-9 was not intended to achieve anything like the 60-miles altitude of the V-2, whereas it might seem logical to assume—in view of the increased powers available—that the A-9 should greatly exceed this figure. The answer is that the V-2 ascended vertically, so that the regions of most resistance should be overcome in the shortest possible time, after which it was turned to follow a path of 45 degrees—the angle for optimum range—for the remainder of the thrust period. Maximum height was reached under *impulse*, as we have already seen.

Take-off for the A-9/A-10 combination was to be arranged in a similar manner, with the booster section supplying powerful but comparatively short-lived thrust. The aim in this case was to outclimb the layers of dense atmosphere and, at the same time, impart the highest possible velocity to the A-9 before it separated.

This phase completed, the smaller rocket accelerated away and, just as power ran out, it would be turned back to earth. Thus, at no time would the A-9 rise under *momentum*, for, indeed, had it done so, its speed on falling back into the lower atmosphere would have been insufficient to permit it to glide.

One might summarise the foregoing by adding that whereas the V-2 required *height* in its trajectory to achieve range, the important factor in the operation of A-9 was *speed*.

Skin Friction

How it was proposed to overcome excessive skin heating at the speeds contemplated for these missiles is not known. Even in the V-2, temperatures were approaching 920 degrees K. at certain critical points on the surface, and had it not been for the effects of conduction and radiation, the figure would have risen to 1,400 degrees K., the stagnation value at a velocity of 5,000ft. per second.

When velocities of over 8,000 m.p.h. are considered—as in the case of the boosted A-9—the stagnation temperature approaches 7,000 degrees K., and, though in practice a considerable reduction may result from radiation, the heat would still be sufficient to affect the propellant system and (in consideration of a later development) to make it decidedly uncomfortable for a crew.

A Piloted Rocket

It had, in fact, been proposed to fit a pressurised cabin and undercarriage to the A-9 so that a pilot could be carried. This would have made the prospect of hitting American targets a much less chanceful business than hitherto, and in this case the explosive (smaller to make up in part for the extra weight of equipment and pilot) would be released to fall on the objective whilst the rocket hurtled past miles overhead, eventually to land in friendly or neutral territory. It is of interest to note that, with propellant and explosive gone, the calculated landing speed was little greater than 100 m.p.h.

For a piloted A-9 to cross the Atlantic, it was found necessary to increase the weight of the booster to 200 tons. This was largely to enable the rocket to accelerate *less rapidly*, though the final speed of the small missile would have been well into five figures as it approached cut-out. Even then the pilot would have to withstand quite considerable "g" pressures (negative in the dive back to denser atmosphere), and what with the frictional heat, it is difficult to imagine an airman of the orthodox school volunteering for the job.

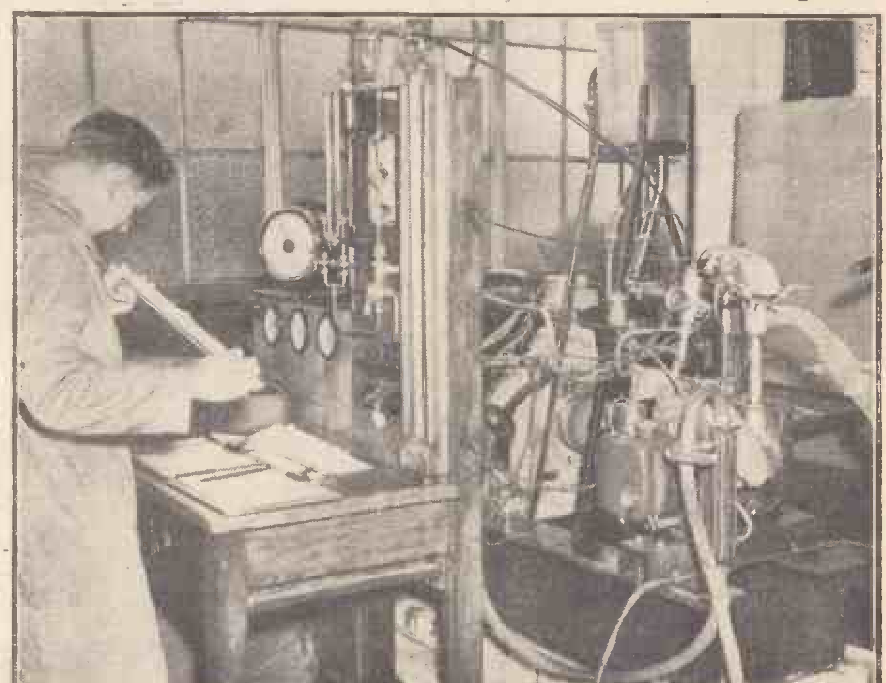
"Future Warfare"

Here, indeed, is a foretaste of future warfare, if such there must be. The rocket and the atomic bomb are clearly inseparable in their rôle of destruction and bring the prospect of "press-button" desolation of entire cities over thousands of miles.

The U.S. Army are reported to have testing rigs under development with which to try out rocket engines for 150-ton projectiles, and this is a clue to the scale of research now being undertaken. Happily, there is another side of the picture, as we shall see in the concluding article.

(*To be concluded*)

Research Work in Motor Industry



The laboratory of the Motor Industry Research Association on the Great West Road, Brentford, has been established for the purpose of providing up-to-date knowledge of technical developments likely to be of use to members. The illustration shows a single-cylinder water-cooled engine that provides data on temperature of the exhaust valve and various parts of the cylinder head.